K.T. CARRAN

Journal

of the

British Interplanetary Society

Volume 12

1953

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Published by
The British Interplanetary Society Limited
London

The BRITISH INTERPLANETARY SOCIETY

LIMITED (by Guarantee)

Secretarial Address: 12, Bessborough Gardens, London, S.W.1.
Telephone: TATe Gallery 9371.

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Journal
of the
British Interplanetary Society

Vol. 12, No. 1 L January, 1953

THE OTHER SIDE OF THE MOON

By H. Percy Wilkins, F.R.A.S.*

From time immemorial it has been known that the Moon always turns the same face towards us. Everybody knows that, unlike the Sun, the face of the Moon is spotted and shaded. These spots are best seen at full moon when the general appearance is that of a somewhat rough-looking human face staring at us, very much after the way in which the Sphinx stares fixidly at the same spot over the sands of Egypt. The earliest savage races noticed this and the Roman historian Plutarch, wrote about "The Face in the Moon," hence arose the age-old expression "The Man in the Moon." In one respect the faces of the Moon and the Sphinx differ—the "Man in the Moon" has been staring for a much longer time. In all probability the moon man has stared at us for millions of years, long before there was any life on the Earth, certainly any human life, and must have seen many strange things happen on our planet. The important thing to note is that whether the Moon is a crescent, a half-moon or full, the face still looks at us from the sky. This can mean only one thing—the Moon always keeps the same side towards the Earth, the other side being forever turned away from us.

Does this mean then that we know absolutely nothing about the other side and can know nothing until the first space-ships take off and men actually land on the Moon? Until recently, people thought so and all manner of curious speculations were made about the further side. The side we see has neither air nor water, being, in fact, an arid desert, plastered over with mountains and vast ring-like objects, the so-called craters; but at one time it was seriously thought that the other side was quite different. There, we were told, were both air and water and, possibly, vegetation, animals or even people. The idea behind this strange fancy was that the Moon was oval or egg-shaped, the pointed end being directed towards us. It was argued that the face we see was a sort of gigantic montain-top sticking up out of the atmosphere and water, which were supposed to be confined to the relatively low-lying other side. This fantastic theory has long been given up and it is now known that there is neither air nor water on any part of the Moon.

Although we said the Moon always turned the same face towards us, the truth is that, like a drunkard, the "Man in the Moon" does sway a little from

* Director of the Lunar Section of the British Astronomical Association and author of a 200-in. map of the Moon.

side to side and also nods up and down and this allows us to peep a little around the edge and see a part of the other side. The proper name for this swaying is "libration" and because of it we can see, at one time or another, one tenth of the other side, or over 100 miles around the edge. Apart from these peeps, why does the Moon always keep the same face turned towards us? There must be some reason for this strange state of things and it is evidently in some way due to the Earth. Some power or force must have been in action to compel the Moon to turn the same face towards us, and then keep it so.

This question leads us into rather deep waters, in fact to the query as to where the Moon itself came from. The argument goes like this. If, as some people have thought, the Moon was originally a little planet moving in a path of its own around the Sun, which path at one point lay close to the Earth's orbit, and eventually came so close that our own planet captured it, then there would be no reason why the Moon should always turn the same face towards us; provided the Moon was already solid. If, however, the Moon ages ago was not solid but fluid, or at least plastic, or if at that time there were seas on the Moon, then the attraction of the Earth would raise enormous tides in the seas, which would act as most efficient brakes and eventually so slow down the Moon's rotation as to cause her to always turn the same face towards us. Even with ourselves, the much weaker tides which the Moon raises in our oceans are slowly, almost imperceptibly, slowing down the Earth's rotation, but it will take millions of years before the Earth turns one and the same face towards the Moon.

On the side of the Moon which faces us the action of the once active tides must have resulted in a sort of bulge towards us, a kind of frozen tidal wave, which is, so to speak, the lever by means of which the Earth having once brought the Moon to a relative fixity, keeps it so. Some people, indeed, regard the craters not as extinct volcanoes or caused by meteors striking the surface, but as due to plastic or molten matter in the interior which has been literally sucked out through weak spots, or "pin-holes" in the crust, by the once gigantic tidal action of the Earth.

As we have said, owing to libration, we can actually see a strip or zone, about 100 miles wide of the mysterious other side all around the borders. In addition to what can actually be seen, we can trace certain light rays which are obviously converging towards foci on the remote hemisphere. Since, on the visible side, the light rays radiate from craters of 20 to 50 miles in diameter, there can be little doubt that the invisible foci are also craters, the approximate positions of which we can plot. Judging by analogy on both the Earth and Mars, there is a sort of balancing on planetary globes, an excess of matter, i.e., a continent or extensive mountainous region, being compensated at the point diametrically opposite by a depression. On the Earth we have the great continental mass of Europe and Asia, with, on the opposite side, the Pacific Ocean.

If this also holds on the Moon, we might expect that the Southern portion of the other side, would be largely mountainous and thus opposed to the so-called "seas" which occupy so much of the Northern portion of the side which faces us. For similar reasons, the Northern part would contain several "seas"

or plains, but these are probably less extensive than the plains on our side, since the results of past tidal action must be far less marked there.

Taking everything into consideration, fact and surmise, what in all probability does the other side look like and how does it differ, both in broad outline and detail, from the side we know so well? In short, can we prepare an advance guide for the space-explorers of the, probably, not far distant future?

The elucidation of this interesting problem has occupied the writer for many years and such parts of the mysterious other side as are brought into view have been carefully scrutinized, first with his own 15¼ in. reflecting telescope and lately with some of the finest telescopes in the world; such as the 33 in. refractor at Meudon and the 25 in. at Cambridge.

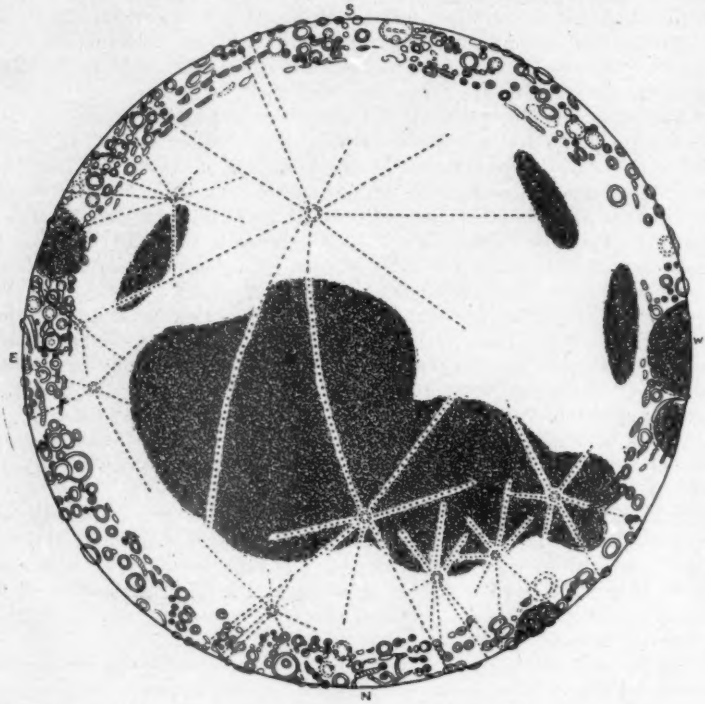
A moment's thought will show the difficulties of properly observing, and hence mapping, the 100 mile zone already mentioned. Even at its best it appears as a narrow strip owing to the foreshortening on the edge of the Moon globe. Mountains will tend to hide such objects as craterlets or depressions of any sort; what nearer the centre of the disc would be a fine, nearly circular crater, is, on this zone, a mere streak; very often only the nearer wall can be detected and its true nature has to be inferred from its shape. It is also easy to understand why large telescopes are necessary for such research. The advantage of a large telescope is that the true nature of whatever detail it does show, is rendered apparent without any difficulty. Some objects in small instruments might be either a mountain ridge or a crater in profile; a speckled region might be covered with either hillocks or minute craterlets; but such possible misinterpretations vanish completely when a giant telescope is employed. We can see at a glance whether an object is a ridge or a crater, a hillock or a craterlet, not to mention the numerous objects which are so small as to be completely invisible in inferior instruments.

But, admitting this, other factors make the charting of features on the very edge of the Moon a slow process. Unfavourable weather, unsuitable libration, the region we wish to examine not being brought sufficiently into view or, given good weather and libration, the region being on the darkened portion of the Moon owing to phase, are the principal obstacles to success, quite apart from the observer himself.

Only by patiently taking advantage of every favourable opportunity and being willing to observe at any hour from sunset to sunrise, can work of scientific value be accomplished, and it requires a certain effort for even the most enthusiastic of observers to get out of a nice warm bed and stand in the frosty, early morning air with, possibly, a chilling wind thrown in as well. Yet the best observations are usually secured under these conditions, and it is at the dead of night, in silence, with the Moon and stars as the only witnesses, apart from an occasional curious cat or hedgehog, that the charting of our neighbouring worlds goes on.

We can conveniently divide the Moon's surface into three parts. First, the portion we always see, about two-fifths of the whole, then the portion we never see, also two-fifths, while the remaining one-fifth is a part all around the edge, half on this side and half on the other, which the swaying first brings into view and then takes out again.

Our chart, the first of its kind ever published, shows the probable appearance of the Moon's other side as it would be seen by anybody viewing it from a distance above the centre; in other words, from a point directly away from the Earth. Our planet would, indeed, be directly behind the Moon and completely hidden by it when the rocket carrying the observer came within 60,000 miles. The writer has found the following features on the other side.



The other side of the Moon.

A large plain or "sea," probably even larger than the Mare Imbrium, or the "Sea of Rains" on our side, covers much of the northern part and probably extends westwards with a bay on the north-west. This bay can just be detected under the most favourable conditions and has been called the Mare Incognito, or the unknown sea, on a special section of the writer's large map of the Moon. There are also smaller plains, the general appearance being that shown on our chart. Anyone can see that if the shading was reversed, the light parts being darkened and the dark areas made light, it would roughly correspond with the distribution of light and dark areas on our side. In other words, elevations on our side correspond to depressions on the other.

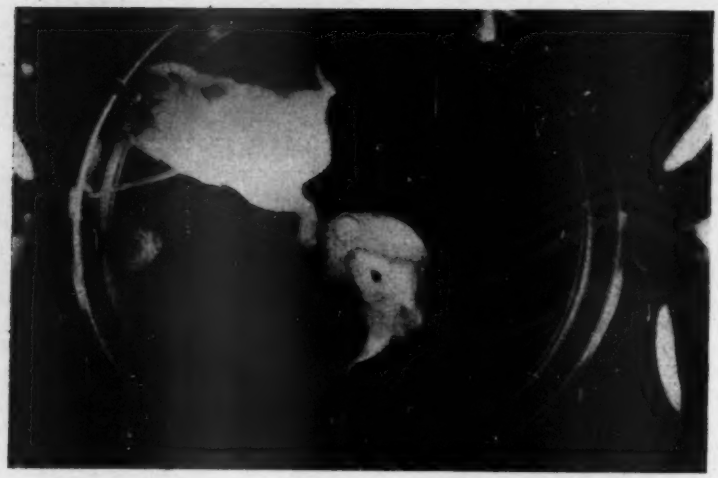
As for details, craters and mountains on the light and dark areas, little can be said and nothing is known with certainty. However, we have traced light rays on our side which obviously converge to foci on the other. Since on our side light rays diverge from conspicuous craters, i.e., Tycho, Copernicus and Kepler, there can be little doubt that there are similar craters on the other side. The converging rays show that there are three such ray centres on the north-western part, four smaller on the eastern part near the Equator and south of it. The chief ray centre, probably a crater 50 or 60 miles in diameter, lies on the south about one-third of the way from the centre to the south limb and a little east of the central meridian. This crater is in the middle of the mountainous region, but those on the north are probably situated on the great northern plains.

Coming near the edge, or limb, we are on more secure ground. We can see the details in these regions as they are carried into view in extreme libration. Great craters, some already named, and lofty mountain ranges, lie on the southern portion. Along the top or south edge are great rings, giant craters and between them great mountain masses towering up into the sky. Some of them can be seen in profile on the very edge itself; the highest is so lofty that it would be necessary to pile two mountains like Snowdon on top of our Mount Everest before we could equal it. It is a veritable, celestial sky-scraper and can occasionally be seen from the Earth. As the east point is approached they become more crowded, while on the edge itself is a small plain, the Mare Orientalis. An almost continuous array of mountains runs from the south-west to the east point, they are the D'Alembert and the Doerfel mountains, some of the peaks of which rise 20,000 feet. Large craters, rivalling the finest on our side, occur along the western edge, but the north polar regions have few lofty mountains. The chief features are large, comparatively low-walled enclosures. The actual pole itself lies within one of them, in striking contrast with the deep craters and lofty mountains on the south polar regions.

The more delicate features such as pits, craterlets and clefts, which exist in great numbers on the side facing the Earth, doubtless also exist on the other side, but it is quite impossible to confirm this supposition by direct observation, owing to the great foreshortening.

This sketch of the Moon's other side, although of necessity imperfect and incomplete, does indicate that the same characteristic features, although with differences of detail, are found on the entire lunar globe.

Anybody on the Moon in what is to us the centre of its face, would naturally see the Earth overhead. But as they move towards what we consider the edge, the Earth would seem to get lower and lower in the sky, until if they camped at a certain spot, the Earth, although most of the time well up, would touch the horizon once every month. As a person went further, more and more of the Earth would be hidden at times until, when they reach the border of the other side, the Earth would be hidden most of the time, and would, to a greater or lesser degree, pop into view once a month. Finally, about 130 miles from the border, the Earth would just touch the horizon without any part of it becoming visible. The travellers would then be literally in an unknown world; but it is hoped that when the first space-ships take off and men actually land on the other side of the Moon, they will find our chart and descriptions more or less reliable guides.



SCENES FROM A MOTION PICTURE OF TWO MICE IN A TWO-SECTION ROTATING DRUM IN AEROBEE III.

The top photograph, made shortly after separation of the rocket nose from the rest of the rocket, and 2 minutes of zero-gravity, shows how the mouse in the rear drum can grasp the sides of his platform to maintain his equilibrium, while the mouse in the front compartment is floating in air during this zero-gravity period. Note that the ball is suspended in air, away from the sides of the drum. The conclusion from this experiment and these photographs is that gravity sense is lost if there is no way of keeping in one place. In other words, mammals who are able to hold on to something can orientate themselves and in no way be affected by the zero-gravity period.

ROCKET FLIGHTS OF MAMMALS TO 200,000 FEET

The United States Air Force recently disclosed that mammals were recovered alive and unharmed after being fired to approximately 200,000 ft. in the upper atmosphere in an Aerobee rocket.

The purpose of the flight was to provide information on the reactions of mammals under conditions of zero gravity and extreme altitude and two monkeys and two mice, the mammals involved, were recovered alive and in good health after the test at Holloman Air Force Base, Alamogordo, New Mexico.

The upper air research programme of the U.S.A.F. Air Research and Development Command has amassed a significant fund of basic scientific knowledge during the past four years. These experiments, under the supervision of the Air Force medical scientists at the Aero Medical Laboratory, Wright Air Development Centre, Dayton, Ohio, were carried out at Holloman Air Force Base, and White Sands Proving Grounds, New Mexico. The testing programme utilized various rocket-type missiles, including V.2's and Aerobees.

From the knowledge gained by these experiments, the Air Research and Development Command has concluded that it is possible for a mammal to function normally during rocket flight.

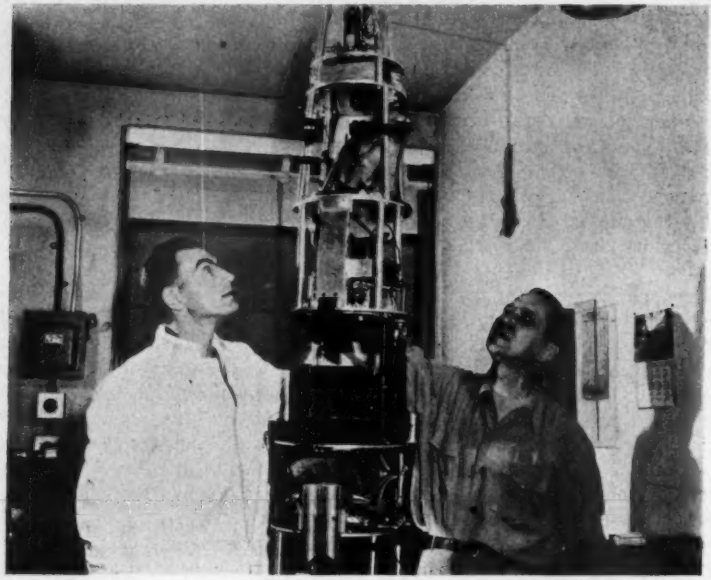
In order to study the physics of the upper atmosphere, it was necessary to perfect telemetering and photographic equipment to record the activities of the subjects during the high acceleration of take off, the weightlessness (zero gravity) at the crest of the trajectory, and the opening shocks of descent and recovery by parachute.

The monkeys and mice experienced no unusual effects from the flight, although they were subjected to a brief initial acceleration of about 15 *g*, lasting less than 1 second, and a longer force of 3 to 4 *g*, lasting for 45 seconds. During this rocket flight, the monkeys were anaesthetized to prevent their disturbing the instrumentation necessary to record their physiological reactions.

Both during the rocket flight and the periods of zero gravity, the mouse in the smooth drum, floating free, appeared to have completely lost his senses of direction and orientation and was unable to direct his movements normally. However, the mouse in the drum containing a small shelf was able to cling to it, orient himself, command his body at will, and did not float in space. These reactions, plus several human experiments in jet fighter aircraft, have indicated that a man, properly secured in an aircraft, can function normally during brief periods of zero gravity and perform any operations necessary in piloting an aircraft.

Continued from previous page

The lower photograph was taken a few seconds after parachute opening when the deceleration applied to the nose cone by the drag parachute approximates one "G." The mouse in the front compartment is standing poised and normally oriented as he follows the drum movement. In contrast with (I) the rubber ball is now supported by the drum. The mouse in the rear compartment prepares to jump off the small shelf with normal agility.



One of the monkeys which was rocketed nearly 40 miles into space. Here, the monkey has been brought into the laboratory and placed in the same rocket head in which he made his historic flight. Mr. Gienapp (right) was responsible for the ingenious methods which were used to fit the recording instrumentation into the small space in the head of the rocket. It was through the recorded results of these experiments that conclusions were arrived at regarding man's reaction to possible zero-gravity flight.

These tests have given added emphasis to Air Force belief that man will be able to withstand the unusual forces expected in rocket flight to the outer atmosphere. It is corroborated from these experiments that little or no loss of physical or mental powers would be experienced in the so-called "zero gravity" or weightless state encountered during rocket flights.

The official Air Force report on these experiments states:

"Physiological results obtained with monkeys and mice can only be applied with caution to men.

"Fortunately, during the past year, two independent reports of pilot performance during states of sub-gravity and near zero-gravity have become available, showing no significant difficulty in performing all actions necessary to control an aircraft during an often-repeated exposure to near-zero gravity state. . . . It may be concluded that, while much remains to be done in this new area, and refined experiments are needed to determine the exact nature of the minor difficulties reported, the weightless state, as it is likely to be encountered for brief one-to-two minute periods in contemporary rocket and jet aircraft, will not seriously interfere with proper performance of a pilot's duties."

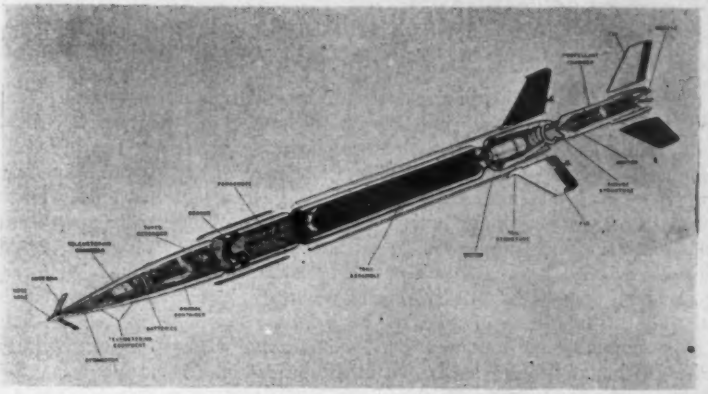


Diagram of an Aerobee Sounding Rocket showing pressurized nose cone with parachute. The nose cone is divided into a forward section carrying the telemetering equipment, and a rear section in which the anaesthetized monkey and rotating mouse drum are placed together with a camera, oxygen supply and sodalime canister.

The senior project officer on these experiments was Dr. J. P. Henry, of the Aero Medical Laboratory of W.A.D.C. Other project engineers who worked with Dr. Henry during the past four years were Captain E. R. Ballinger, U.S.A.F. (M.C.); Major P. J. Maher, U.S.A.F.; and Captain D. G. Simons, U.S.A.F. (M.C.).

U.S. Air Force Research and Development Command installations involved in these experiments were: Aero Medical Laboratory at Wright Air Development Centre; Electronic and Atmospheric Branch of Holloman Air Force Base, New Mexico; and Geophysics Research Directorate, Air Force Cambridge Research Centre. Other supporting installations were White Sands Proving Grounds, New Mexico; and the Parachute Branch, Equipment Laboratory, Wright Air Development Centre.

[*From Department o Defense Press Release, September* 26, 1952.]

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SECOND SYMPOSIUM ON SPACE TRAVEL

HELD AT HAYDEN PLANETARIUM

Columbus Day was again chosen for the Second Symposium on Space Travel, held at the Hayden Planetarium, New York, on October 13, 1952. Willy Ley co-ordinated the symposium and introduced the speakers. The proceedings opened with a talk by Robert R. Coles, Chairman of the Hayden Planetarium, who spoke on "The Role of the Planetarium in Space Travel," and who mentioned that the Zeiss projector at his institution had given displays to nearly half-a-million people during the previous year.

Willy Ley then gave a talk entitled "Attack on the Third Dimension," stressing the point that present-day travel is still essentially two-dimensional and that astronautics will therefore be a totally new type of experience.

The remaining speakers were Dr. Fred Whipple, George O. Smith, Dr. Fritz Haber, Milton W. Rosen, and Dr. Wernher von Braun. Their papers (shortened in some instances) are reproduced below.

ASTRONOMY FROM THE SPACE STATION

By Fred L. Whipple, Ph.D.

(*Chairman, Department of Astronomy, Harvard College Observatory, Cambridge, Mass.*)

I am going to limit my discussion to the purely astronomical problems which will face the astronomer when he begins an observational programme to be undertaken from an observatory located above the Earth's atmosphere. I am going to omit intentionally the exceedingly important observations of the Earth, particularly those meteorological and geophysical in character.

The astronomer must first design and locate an observatory that can be operated under the extremely unusual conditions in empty space. There are some very interesting problems concerning the simple matter of locating the observatory with respect to the satellite station. The only really practical location is in the precise orbit of the satellite vehicle, ahead or behind; otherwise an oscillation normal to the orbital plane will occur in each revolution as well as drift motions away from the satellite vehicle. In 24 hours the drift is nearly 40 times the distance towards or away from the Earth with respect to the station orbit. The observatory could even be placed in such a fashion that it describes a circular orbit about the station, without being attached to it. This solution to the problem, however, is not a desirable one, since the station comes within the line of sight of the telescope too frequently. The astronomer would really wish to have the observatory at a greater distance from the Earth than 1,075 miles, because of the large solid angle of the Earth as seen from the orbit.

A number of technological problems with regard to the operation of the instrument must be considered and solved. Covering the surface of the mirror with a metallic reflecting coat, however, will be the easiest of all became of the complete vacuum in space. Furthermore, much electronic equipment will

operate without the complication of vacuum seals, which constitute a considerable problem of electronic design and construction in a gaseous medium like our atmosphere. Various problems, such as orienting the instrument, holding its position accurately, etc., are of great interest in technological design. The question of shielding surfaces from rapid temperature changes produced by the Sun and Earth is also a very important one. The observer will not be able to touch the telescope nor be within it, because of the precise directional control required for most problems. Hence all guiding will be remote control, as well as opening shutters and other operations. The changing of films and plates can best be done by remote control, storage units being transferable to the telescope from the satellite station.

The spectroscopic techniques used in the satellite station will be adaptations of laboratory techniques now used in vacuum for the far ultra-violet, X-ray and gamma rays. Because of the universal vacuum surrounding the station, many of these electronic problems, photoelectric problems, etc., will be greatly simplified. Large regions in the radio spectrum will be opened up by the existence of the station above the ionosphere, and we may expect a large branch of radio astronomy from the satellite vehicle. Furthermore, there exists the possibility of constructing rather large antennas in space, so that the resolving power of radio astronomy may be greatly increased.

The useful electromagnetic spectrum ranges at least over a power of 10^{20} in wave-length or frequency. The eye sees over scarcely a range of 2 in this 10^{20}, while the infra-red and ultra-violet transmission of the atmosphere permits a range of about a factor of 10. Recent innovations in radio astronomy open up a vast range of some 30,000 times from about 1 millimetre to 30 metres wave-length. Extremely great progress is being made in this range of the spectrum, but the most interesting parts, which lie in the ultra-violet, X-ray and gamma ray regions, are completely invisible from the earth's surface. Modern rocket explorations have made great strides in solar studies over these far regions. The entire spectrum from less than one angstrom unit in wave-length (10^{-8} cm.) up to radio-type waves comparable to the dimensions of the Earth can all be observed from the satellite station.

The over-all astronomical fields of research to be covered will include (*a*) solar problems, (*b*) the planets and smaller bodies in the solar system, (*c*) the stars, (*d*) the galaxies and (*e*) the interstellar medium of gas and dust. It is staggering to think of the innumerable intriguing observations that one can hope to make from space.

The solar problems will undoubtedly be handled by small, specialized equipment of several varieties, each designed to attack a special problem of solar structure and activity. The present rocket programme in the United States will give us preliminary information on many solar phenomena occurring in the far ultra-violet and X-ray region. We will be particularly interested in the direct measurement of corpuscular radiation from the Sun, the far ultra-violet and X-ray spectra and variations as correlated with solar activity such as prominences, flares, corona, etc. It is possible also that from space radar observations of passing corpuscular streams can be made. Perhaps the question of cosmic ray sources in the Sun will have been solved by the time the satellite

observatory is ready, but certainly there are many studies of great interest bearing on this problem.

The planetary problems will make use of the high-resolving power of a large telescope, with say a 100- or 200-in. mirror. On Mars, for example, a resolving power of approximately 10 miles should be possible with a 100-in. telescope. Of equal interest will be a study of the complete chemical composition of all planetary atmospheres, since the far ultra-violet light will reveal the presence of molecules and atoms that do not absorb light in the photographic regions or, such as water vapour, are largely absorbed in our own atmosphere. Detailed observation of the composition of cometary atmospheres will be invaluable, not only with regard to the evolution of planets, but concerning the possibility of life on them.

In stellar astronomy, a huge endeavour involving spectroscopy in the far ultra-violet and X-ray region, even in the gamma-ray region will provide any large telescope, or even several of them, with problems for generations. Problems of stellar composition can be solved for all elements that are present even in exceedingly minute quantities, but I expect that the cream of these researches will have been skimmed by the great progress at present in the photographic spectrum. Nevertheless, the extent of the spectroscopic astrophysical field of endeavour is so great that innumerable new problems will arise and be solved in the early years of the satellite station. These problems particularly concern not only the nature, composition and evolution of stars, but the processes going on in the atmospheres, particularly loss of material, circulation of great clouds of material about double-star systems, and possibly in some cases the accretion of matter from the interstellar medium.

If the nature of stellar evolution has not been thoroughly outlined before the satellite station is built, there is no question but that the space observatory will speed the rate of solution by a large factor. Furthermore, it will be possible to obtain clear insight as to the spectacular novae, super-novae, peculiar variable stars, huge giants, and extremely hot stars, as well as the white dwarfs of extremely high densities.

A very important problem that will probably not be solved before the space observatory will be that of the composition of the interstellar medium. Beyond the Earth's atmosphere, it will be possible to determine the percentage of almost all trace elements in the interstellar medium: through the Earth's atmosphere, even with radio astronomy techniques, only a very few of them can be isolated. The importance of this problem becomes apparent when we realize that many of the great gas and dust clouds of the Milky Way are stellar incubators in which new stars are, indeed, at the present time being born. We know that we observe many ancient stars, three billion years old or more, and at the same time a number of youngsters, perhaps only a hundred thousand years in age. There are already indications of fundamental differences in composition between these two groups of stars, young and old. Many questions of the greatest import in evolutionary problems concern the way in which the interstellar medium may have changed composition during the three or four billion years of universe history. Possibly these changes have occurred by selective accumulation of stars from dust, rather than the gases, perhaps by the addition of

heavier elements to the stellar medium by explosions of stars and nuclear changes within them, or possibly matter is being created at the present time, as Hoyle has suggested.

The observatory in space may well reveal the secrets of the origin of the universe itself. The most important problems for the space astronomer may then become new ones, beyond the horizons of our science to-day.

RADIO COMMUNICATION ACROSS SPACE—SHIP-TO-SHIP AND SHIP-TO-PLANET

By George O. Smith

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At first glance, radio communication across space looks like a major project. The Moon is 238,000 miles away. This appears to be an unsurmountable barrier if it is compared to the service area of a 50,000 watt broadcast station. However, space radio should not be compared to any terrestrial experience for the obvious reason that planetary conditions do not obtain in space.

For instance, the theoretical distance across which radio signals can be sent seldom meets the actual conditions. This is due to the fact that our atmosphere is not an entirely transparent medium for the passage of electromagnetic waves. Transmission distances are affected by the frequency of the radio signals, the topography, the electrical condition of the soil, the time of the day and the season of the year, climate and meteorological conditions and, last but not least, the era of the sun-spot cycle.

If the earth were an airless planet, the distance across which a transmission could be made would be the geographical horizon for all frequencies, because electromagnetic waves tend to propagate in straight lines unless acted upon by some outside force.

But the solar output causes layers of ionization in the upper, rarified portion of our atmosphere, and these several layers cause reflection or absorption of radio waves that impinge upon them.

The other conditions mentioned are variable, so that the following statements are generalities instead of being firm and inviolate:

Frequencies below the top of the broadcast band are influenced by the electrical condition of the soil and the activity of the lower ionosphere, called the "D Layer." Transmission beyond the horizon is fairly constant and reliable.

Frequencies above the top of the broadcast band are less affected by ground conditions. These frequencies pass through the lower ionosphere but are caught by the upper layers *E*, *F*-1 and *F*-2. Transmission beyond the horizon is spotty and sometimes a bit fantastic. A transmitter in New York can be heard with clarity in Los Angeles, while a receiver in Philadelphia cannot get a trace of the signal. Other conditions may produce readable signals also in Chicago and Denver as well as Los Angeles while points between these cities are totally blank.

As the planet rotates, bringing new areas under the direct rays of the Sun, the layers shift in altitude and activity. This can produce a situation whereby a radio contact may be held between two widely separated places like Chicago

and New Zealand for a two-hour period while the layers are shifting above the transmission path half-way between the two places. The signal will come in strong and clear for about two hours and then will fade out completely until the same time next morning.

These skip-layers have been mapped and charted so that if we pick our frequency, and the time of the day, and season of the year, we can predict with a fair degree of accuracy whether we can make contact with a certain place.

But as we inspect the radio spectrum above fifty megacycles, which is the normal Television band, we discover that the atmosphere is becoming more and more transparent. Except under freak conditions, frequencies above fifty megacycles pass through the ionosphere and into space. This is why the general service area of a television transmitter tends to be that of the geographical horizon. Stations below fifty megacycles are reflected back from the ionosphere to some point beyond the horizon.

In a sense, this difficulty with terrestrial radio communications is similar to the problems of space travel. All the problems seem to lie below the first 500 miles of altitude.

One in space, radio travels in straight lines through an absolutely transparent medium. There are no natural barriers in space; there is nothing to cause reflections or refractions, any of which can cause the received signal to vary greatly from the simple formulas for radiated power.

Out in space we can express our communications system in a mathematical equation and expect it to hold firm. Radio signal strength, like light, diminishes proportionally to the inverse square of the distance. We can compute, therefore, just how much signal we will have left at the end of a given distance. Or conversely, we can compute how much signal we will have to start out with if we require a given amount for good reception across that distance. This formula is:

$$P_t = \frac{\beta_1 \beta_2}{40} \times \frac{BL^2}{f^2 r^4} \times \left(\frac{F}{K}\right) \sigma \left(\frac{S}{N}\right) \quad \ldots \quad \ldots \quad (1)$$

The unknown, P_t on the left, is the power of the transmitter as stated in watts. The rest of the terms on the right will be explained later. At each step we will replace the term with the appropriate numerical statement until we can sum this up by plain arithmetic and get our unknown transmitter power.

Perhaps the best place to start is at the end. S/N is the Signal-to-Noise ratio. This will be about the same for any communications system we care to design, so let's take care of it first.

Noise is the bugbear of communications. Interference from other stations and just plain random noise are two of the important factors that limit the useful range of any radio equipment. Noise comes of two basic causes, natural and man-made.

Natural noise is created mostly by lightning and coronal discharges in storms and bad weather conditions, either locally or at some distance.

Man-made noise comes from the fact that men learned more about electricity than they have about radio, and much sooner. Electrical machinery, diathermy equipment, X-ray devices, electric razors, automobile ignition systems,

door-bells, and anything else that the human race has learned to do by electricity, all succeed in creating noise.

Noise in space is all natural. There is galactic noise, first discovered by Dr. Jansky in 1933, and since then expanded into the study of radio astronomy. There seem to be a lot of dark stars that radiate radio waves of one frequency or another. This noise is not of a high level and the spectrum is spotty and discontinuous so that a convenient gap can be used for space radio. The second type of cosmic noise is thermal noise. Solar activity throughout the galaxy produces energy that radiates along a continuous spectrum. This radiation is of equal amplitude across wide bands and its time-amplitude curve is non-recurrent. In other words, it is just plain noise, differing from galactic noise in that the latter does have definite radiation frequencies. The third type of cosmic noise is anomalous solar radiation which comes from Sol and tends to rise and fall with the Sun-Spot cycle.

Now, the signal-to-noise ratio must always be greater than unity. In fact, a one-to-one signal-to-noise ratio is a completely hopeless signal to read. A ten-to-one ratio provides better intelligibility, but even here the random noise peaks can frequently coincide with some difficult sound of the voice and cut a hole in the flow of intelligence.

Signal-to-noise ratio also depends upon the individual listening, the person talking, and the importance of the message. A fine symphony can be ruined by a noise factor that might be considered only a petty annoyance to a man whose life depended upon listening carefully.

The voice of the speaker has a lot to do with deciding upon an acceptable signal-to-noise level. Some voices seem to cut through a noise level when others are blanketed. This has to do with enunciation, voice pitch, and the rapidity with which the words are articulated.

The hearing ability of the listener is another important factor. Some people are extremely sensitive to bursts of noise which tend to cut into their concentration level and cause them to miss some of a message. Other people can listen to a conversation through a rather heavy noise level and not miss a syllable.

These are the reasons why the signal-to-noise factor is expressed as a fraction and not a generally accepted constant.

However, we know that our expeditionary party on the moon is important. Let's take a mixture of one part noise to one hundred parts signal and enter the figures in our equation. This equation now becomes:

$$P_t = \frac{\beta_1 \beta_2}{40} \times \frac{BL^2}{f^2 r^4} \times \left(\frac{F}{K}\right) \sigma \frac{100}{1} \qquad .. \qquad .. \qquad (2)$$

The next term in the equation is Sigma, and represents a sort of safety factor. It stands for the probability of signal fading. The atmospheric conditions we experience here on Earth cause alternate reinforcement or cancellation of radio waves, depending upon varying conditions of the ionosphere. Shifting of the ionized layers as the Earth rotates to bring a new area into the sunlight region is known to create conditions where a signal may take two paths in its course from transmitter to receiver. One course may reinforce the signal, while another may cause cancellation of the signal. The result is fading, and anyone

who has ever listened to the short-wave bands will understand how this strengthening and weakening of the signal can affect communications.

We do not expect to find any such conditions in space, but there may be conditions of the upper atmosphere that will affect the signal strength as we aim our radio at the Moon.

The signal-to-noise ratio mentioned previously is based upon the minimum requirements; if for any reason the signal is attenuated along the way, this loss must be made up at the transmitter. We do not care how strong the signal is so long as it never falls below the receivable level.

I believe that a fading factor of ten should be adequate to cover any contingency. In this I confess a lack of experience and data. Until someone succeeds in establishing a radio receiving station in space, at which the signal strengths can be measured with accuracy, no one can do more than hazard a guess. But a figure of ten-to-one in signal strength variation due to upper atmospheric conditions is a rather pessimistic opinion.

So we will replace the letter Sigma with the numerical ten, to stand for a ten-to-one safety factor against fading.

Our equation at present reads:

$$P_t = \frac{\beta_1 \beta_2}{40} \times \frac{BL^2}{f^2 r^4} \times \left(\frac{F}{K}\right) 10 \left(\frac{100}{1}\right) \quad .. \quad .. \quad (3)$$

The foregoing terms are likely to remain about the same no matter what form of radio communication we use. This is why we disposed of them first. But now is the time to discuss the spectrum which will be used in space radio.

I have mentioned that the atmosphere becomes reasonably transparent to the microwave bands. The microwave frequencies lie between approximately 1,000 and 30,000 megacycles. They are called microwaves because their wave-length is extremely short. So short, in fact, that it is far easier to measure the wave-length than it is to measure the radio frequency.

These microwaves are used in the several radar systems. Therefore equipment has already been designed for their efficient use. We have had quite a bit of experience with microwaves so that we can predict their performance with a good degree of accuracy. Microwaves are also excellent carrier waves for our space radio because they are easy to confine in a tight beam using antenna arrays of a convenient size. Such reflectors can be handled with ease, either on the Earth, on the Moon, or in space.

The spread, or dispersion, of any beam is a function of the wave-length of the radiation and the area of the antenna array. The wider the reflector, the narrower the beam will be for a given wave-length. This can be given approximately by a fairly simple formula:

The angle of dispersion in degrees is equal to 6·7 times the wave-length, divided by the width of the antenna.

The selection of a microwave band can be justified by this formula alone. A 6-ft. reflector, using three centimetre microwaves will produce a beam about 1° in spread. Since the Moon subtends an arc of a half degree, our beam will cover more than the face of the Moon if we use three centimetre microwaves and a 6-ft. parabolic reflector.

The question will arise as to why we permit the beam to splash out across waste space. Why not use a reflector, similar to the radio telescope down at the Naval Research Laboratory? This is 50 ft. in diameter, mounted on gimbals, and is used in the study of radio astronomy. Such a reflector would be extremely efficient, producing a beam of three centimetre waves less than 0·15° in spread. However, I have selected the 6-ft. parabolic mirror because we can and have produced them in mass. Furthermore, its handling would be less of a major project. A 50-ft. mirror in space could be quite a job, not through handling under free-fall conditions, but because of taking it aboard the space-craft in segments and then putting the segments back together again once the ship was in space. Also the big mirror would have to be disassembled before the landing on the Moon, and then might give some trouble during the stay there. It seems to me that the crew would spend more time taking the big reflector apart and putting it together again than they would in using it for space communications.

A mirror of that size, even made of a perforated type of construction, adds quite a bit of mass to the pay-load of the ship. On the other hand, a 6-ft. parabola of aluminium can be carried with ease by one man. Without a doubt, the big radiators will be built after space travel becomes a regular thing. But for the present and some time to come the smaller parabolic mirror will be ample.

I also wish to point out that having a tight beam, one of less than 0·15°, provides the operator with quite a bit of trouble. In receiving, as the 50-ft. mirror is used exclusively, the operator can turn his antenna to the direction that actually gives him the strongest signal. But in transmitting, all the operator can do is point his antenna and hope that the beam he is pouring out is hitting the right spot. A feedback loop from the receiver could probably be constructed, but this strikes me as complicating a simple programme just for the benefit of using a more efficient antenna. I can easily imagine a pair of operators spending most of their time adjusting the antennas instead of using their radio power for getting a message across.

Accepting a 6-ft. parabolic mirror for our antenna array because of convenience, availability and compromise, and using this with three centimetre microwaves provides us with a fair beam spread and also the tolerance necessary to point the beam and be certain that the spread is covering the target.

Three centimetre microwaves have been selected because of the availability of equipment. Waveguides for this band have been built for several years. The duplexing assembly which permits the use of the same antenna for transmitting and receiving can be bought from a number of sources. Microwave receivers as well as transmitters exist. We need only buy a surplus "X-Band" Radar equipment and convert it to communications use and our system is set up and ready to go to work.

We might gain an advantage by going to a shorter wave-length, but we find that we are stepping close to the danger point. Water vapour has a resonance absorption band at 1·3 cm., and oxygen has resonance bands at 0·5 and 0·25 cm. These absorption bands are characteristic of the atomic spectrum, which in the region of visible light produce the Fraunhofer Lines.

Let's remain with three centimetres. It is a convenient figure and I like it.

Now, three centimetres corresponds to a frequency of 10,000 megacycles. The small letter f in the formula, represents the frequency, and the small letter r stands for the radius of the parabolic reflector in feet.

Our equation now becomes:

$$P_t = \frac{\beta_1\beta_2}{40} \times \frac{BL^2}{81 \times 10^8} \times \left(\frac{F}{K}\right) \times 10 \times \left(\frac{100}{1}\right) \qquad (4)$$

Having decided upon a frequency, it is now proper to discuss another source of noise, and what we can do about it. This is the noise generated in the receiving equipment itself.

The flow of electrons along a wire, through a resistor, or their emission from a tube cathode is never smooth and even. The energies in this electron flow follow Maxwell's Law of Random Distribution of densities and energies and motions. I have heard a rather quiet, sincere professor state that the flow of electrons is as smooth as dumping a load of soft coal into an empty cellar.

Electrons vibrate all the time. They vibrate faster when heat energy is introduced. The cathode must be hot before the electrons will emit. Current passing through a resistor produces heat. Therefore there is always a low level racket going on right in the receiver itself.

This is known as thermal noise and if you will pardon the heartfelt expression, it is a darned nuisance.

Thermal noise can be computed with accuracy. The figures include Boltzmann's constant, the temperature of the device under consideration, and the bandwidth of the listening amplifier. The resulting figure is a noise output stated in watts. This thermal noise level is the theoretical limit of the sensitivity for any amplifying equipment.

Radio equipment for a good many years has been sensitive almost down to the theoretical limit. In the broadcast band we can design a receiver with a noise figure of merit not more than two or three. In the short-wave bands our equipment loses its efficiency and the figure begins to creep up. In the microwave region, the inherent noise in the sensitive elements of the receiver rises to a rather distressing figure. Some equipments have been designed with noise figures as low as 40, but the general run of the mill tends to be higher than this.

I will accept the noise figure of merit for a fair microwave receiver as being 100. This figure of merit goes in the place of the capital F.

$$P_t = \frac{\beta_1\beta_2}{40} \times \frac{BL^2}{81 \times 10^8} \times \left(\frac{100}{K}\right) \times 10 \times \left(\frac{100}{1}\right) \qquad .. \qquad (5)$$

Now, one way to overcome this noise problem is to use a signal of high power. This is why we seldom notice noise levels in our home receivers. But this computation we are making is to derive the minimum required power at our transmitter. Then anything we can produce above this minimum will be a bonus.

Another way to lick the noise problem is to use a mode of transmission and reception that is inherently less subject to noise.

Noise is of random nature and invariably amplitude modulated. Therefore, the old-fashioned broadcast band with amplitude modulation is about as noisy

as we can get. Amplitude modulation has for a noise-improvement factor the figure unity. That would replace the factor K below the line under our receiver figure of merit term F.

For frequency modulation, which everybody knows is less subject to noise than amplitude modulation, we have a noise improvement factor K that can be computed from the system constants.

The noise improvement factor is, for frequency modulation systems, equal to three times the square of the ratio between the carrier frequency deviation and the maximum modulation frequency. Since intelligible speech requires a minimum of 5,000 c/s., and a carrier deviation of 100 kc/s. is an efficient figure for F.M. transmission, our figure K becomes 1,200.

Entered in the equation, we now have:

$$P_t = \frac{\beta_1\beta_2}{40} \times \frac{\cdot 005L^2}{81 \times 10^8} \times \left(\frac{100}{1200}\right) \times 10 \times \left(\frac{100}{1}\right) \quad .. \quad (6)$$

I have also entered the bandwidth figure B as 5,000 c/s. because we will want to receive everything that is being transmitted, but lose nothing. Therefore the receiver bandwidth must be equal to the transmitter bandwidth.

As we well know, nothing can ever be put together to work perfectly. Therefore are the two factors β_1 and β_2. These represent the losses we will experience in connecting our transmitter to the antenna through a wave guide, β_1; and the return losses caused by connecting our receiving antenna to the receiver input through a similar wave guide, β_2. I have been forced to accept a loss of two to one in each case. It sounds deplorable to throw away 50 per cent. of our radio frequency power before it even gets out of the antenna, but these are the conditions that prevail. Considering that a locomotive is less than 10 per cent. efficient and that the gasoline engine is less than 25 per cent., we can all be glad that energy and power are cheap and plentiful.

Our equation now becomes:

$$P_t = \frac{2 \times 2}{40} \times \frac{\cdot 005L^2}{81 \times 10^8} \times \frac{100}{1200} \times 10 \times \frac{100}{1} \quad .. \quad (7)$$

There is one more term. Like all the rest of the terms that work against us, this one lies above the line, and it is the distance between here and the Moon, stated in statute miles.

Furthermore, this figure is squared.

I have been asked repeatedly whether or not a beamed signal avoids the radiation loss of the inverse square law. I wish it did, but it doesn't! On the face of it, it looks logical to assume that there will be less loss when the signal is crammed into a tight cone than there will be if the signal is permitted to radiate wide open. The unfortunate part of it is that no signal can ever be confined into a perfectly collimated beam. The formula for beam dispersion, if reduced to the final absurdity, shows that for a perfectly collimated beam, the antenna must be infinitely wide.

So no matter how much we dislike to take this loss we must accept it.

The distance from the Earth to the Moon is 238,000 miles. Squared and inserted in our formula this produces a figure of $56{\cdot}7 \times 10^9$.

Now we can put this set of figures on the calculating machine and the answer can be derived.

The minimum required power output to provide communication between the Earth and the Moon is:

$$P_t = \frac{2 \times 2}{40} \times \frac{\cdot 005 \times 56{\cdot}7 \times 10^9}{81 \times 10^8} \times \frac{100}{1200} \times 10 \times \frac{100}{1} \qquad (8)$$

or $P_t = 0{\cdot}291$ watts.

Maybe we had better move our expedition out to Mars so that I can say something sensational?

291 milliwatts is about the power used in a three-cell flashlight.

At this point I should like to lay a ghost.

Time and again someone has suggested the use of blinker lamps or heliograph for interplanetary communications. I would like to see how far anyone can get with a three-cell flashlight, winking the thing at the Earth from the Crater Plato. Or conversely, flashing the same at Plato from White Sands.

Yet if the same formula is used for the frequencies for visible light it should come out the same. The trouble is that the factors are different, and most of them deleterious. The skies provide a very high noise level, if you can think of zodiacal light and the lunar brightness in terms of a noise threshold. The bandwidth of the visible spectrum is expressed in a fantastic figure in megacycles. Haze and overcast raises our safety-factor number, and the human eye, when dark-adapted, is troubled by internal lights which are of the same order as thermal noise.

However, three centimetre microwaves can pass through an overcast sky. We have a formula for approximating this, too. It has to do with ten times the rainfall in inches over the past 24 hours divided by the square of the wavelength. (This, admittedly, is crude.)

In fact, about the only thing that may change communications as we know it will be time lag. The Moon is 2·6 seconds away for the round trip. This means that 2·6 seconds must elapse between question and answer. I have prepared a phonograph record that demonstrates the following factors in Earth-Moon communications:

(1) The time lag. Here the recording is made to simulate the earthside station. Our operator can reply as soon as he hears the other end.

(2) The noise level of our receiver with no signal between communications.

(3) The quieting as the signal comes in, arriving on an over-all signal-to-noise ratio of approximately 100 to 1. Some noise peaks come in almost to the 10-to-1 level.

This recording was cut at home under controlled conditions, the only part of which is not quite fair is the standard practice of using a filter microphone to create the dramatic effect of the use of transmission equipment. Here the bandwidth is a full 5,000 cycles, but the lower register has been cut.

(At this point, Mr. Smith demonstrated the recording.)

I am not going to play a record simulating a Mars communication. It would take six minutes between statement and rejoinder. The power, incidentally, would be about 7,000 watts to Mars, which might begin to offer us a challenge. On the other hand, the use of one of those 50-ft. antennas I mentioned before, would bring the requirements to less than a 1,000 watts. This would put us back in business again.

But I have been discussing our interplanetary network in terms of voice modulation, as if it were a telephone system. The preference of telephone over telegraphy is, here on Earth, a matter of convenience and speed. A man in New York can call a business associate in Los Angeles and place a verbal order, at the same time discussing price, delivery date and probably their golf scores. A telegram will permit similar interchange of intelligence, but it will require longer to complete the whole transaction.

Since I doubt that there will be much interplanetary exchange for purely social purposes where the personal voice-to-voice contact is the most desirable, it seems to me that quite a bit can be done with a radio teletype system.

We can only guess until we get there, of course, but we can make a fairly shrewd guess as to the nature of any interplanetary messages that will take place for some time to come. The only business transacted will be of scientific or military nature. No one is going to set up a transformer plant on Mars, or start making automobile tyres on the Moon.

It has been suggested that we may find valuable minerals elsewhere in our solar system, but if we accept the opinions of the astronomers and astrophysicists regarding the proportion of the elements throughout the universe, the chances of stumbling upon a lode of uranium ore seem no greater than the chances of finding the same thing here on Earth. This rules out the possible mining industry.

Therefore, it is my opinion, that most of the communications that will take place will be the transfer of technical data, the forwarding of instructions, and other information of a totally non-personal nature.

Such information is better transmitted by a teletype system. The result is a roll of paper upon which the facts and figures are recorded for future reference. No operator need write like mad to take down a string of figures as they are spoken and thus take the chance of making a mistake. The teletype machinery offers an excellent cross-check. With the teletype machine it is possible to have a tape punched of the received signal, at the same time that the typing section is recording the message. At the end of such a reception it is possible to retransmit the tape recording back to the point of origin. Any discrepancy between the original transmission and the reply-copy can be investigated and corrected.

Teletype requires less bandwidth than voice modulation by a factor of about 25 to 1, thus giving us a signal power advantage of that figure. Furthermore, the signals that operate teletype equipment are pulsed modulation, which again offers an advantage in the noise-improvement factor K.

To top this off, pulse modulation offers a valuable increase in power over and above the noise improvement factor. Our work with pulsed magnetron transmitters in radar equipments show that the signalling factor with pulsed

power depends upon the peak power delivered and not the average power. The pulsed magnetron delivers a wallop of power during the operating cycle and then rests for a comparatively long period between cycles. For instance, if our pulse length is one microsecond and our pulse repetition rate is 1,000 c/s., an average power input of 100 watts results in a pulsed power output peak of 100 kilowatts.

If we take advantage of all of these considerations, teletype transmission on pulsed modulation can provide good service in space radio all the way across the solar system from here to Pluto, if we get that far from home.

So despite the fact that the Earth-to-Moon link would only have a time lag of 2·6 seconds, I would recommend the teletype system due to the permanence of the record of such transmissions. It is true that voice can be recorded with ease, but considering that most of the information that will be going back and forth is likely to be of highly technical nature, the written record is by far the most accurate.

For truly short-range communications, such as we will find in the orbital station-to-Earth link, both audio and teletype systems should be employed. Anyone who has ever listened in on an airport tower frequency must have been appalled at the amount of rapid chatter that goes into the business of getting planes into the air and back down again. Such chatter cannot be handled by teletype or any of the slower forms of transmission. I have a feeling that the orbital station radio centre is going to be loaded 24 hours every day with requests for information about climatic conditions over Hawaii, requests to relay such and such to Alaska, and information and reply, and so on. Voice radio is the thing for this.

And, of course, as each spacecraft rises out to the station level it will go on short-range radio, voice modulated, while the ship is matching velocity, course, and orbit with the station. The picture in the end-papers of the book *Across the Space Frontier*, shows the arrival of a rocket, the orbital station, the space telescope, and a couple of space taxis, along with several men in space suits. Since it is virtually impossible to handle a four-oar row boat without a lot of chatter, the short-range radio is going to be a busy channel.

The ship-to-ship communications in fleet operations will be conducted in voice. Radio equipment like the current handy-talky that weighs about 8 lb. will serve admirably. I have used such equipment over a distance of several miles, and I feel that in free space the range might be extended somewhat. This should be adequate. A fleet of three spacecraft heading for the Moon should never get much more than a mile or so of one another. Therefore, the light equipment should do the trick.

This same equipment will also be included as standard for all space suits. Two men out in space on the hull of a ship will be using such radio even though they are standing only a few feet apart. The use of cables and plug connections for close-quarter operations has been suggested, but I cannot see why a cable-reel weighing a half-dozen lbs., plus the nasty tangle of wires, would justify itself, especially where the suit must have radio gear anyway.

Long range ship-to-ship is another thing that I cannot justify. I fail to see why it should be necessary for a ship *en route* to Venus to get in touch with

another ship heading for Mars. Yet if this should become necessary, the way to do it is to relay the message from ship to Earth to ship. It would be far easier because the earthside station will be keeping its antennas trained on both ships all the time, whereas it might be difficult for one ship in space to aim an antenna at another ship in space. Furthermore, the second ship, not knowing that the first wanted to call, would not have its receiving antenna trained on the first.

I have not mentioned transistors in this talk because the use of transistors is a foregone conclusion. Transistors will be used whenever they fill the bill for two reasons. One of the reasons is the matter of power requirements. Transsistors drink up a lot less power than vacuum tubes. They are lighter and smaller. Since transistors can be made to do almost anything that a vacuum tube can do, naturally we will use them. However, the heavy-duty power transistor lies still in the future, and I anticipate that we will stick to the magnetron to generate our microwave power.

I have one suggestion to make to the designers of space stations and spacecraft. It would seem that both schools have included some sort of solar heat gadget for system power. The mercury boiler system, heated by a mirror from the Sun, has been drawn in carefully in the book *Across the Space Frontier*, but frankly I have a better suggestion. Just forget the mirror and run your mercury through a heat exchanger located in the radio equipment and do both jobs at once. A three centimetre magnetron in a radar equipment delivers both a wallop of power and enough heat to warm a four-room house. I think that the big problem is to get rid of the heat instead of collecting more of it from Sol.

And so in conclusion, we can assume that radio communication will not find the astronomical distances an insurpassable barrier, and we need not envision a monstrous installation pouring millions of kilowatts into the sky. We can take pride in saying that the interplanetary network could be set up to-day if we had someone at the other end to receive the signals.

I also have little doubt that by the time we get someone out there to receive radio messages, the art of communications will have taken another step forward and these carefully made suggestions will have become obsolete.

THE EARLY STEPS IN THE REALIZATION OF THE SPACE STATION

By Dr. Wernher von Braun

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The conquest of space represents the outstanding challenge to science and technology of the age in which we live. Ten to fifteen years from now, depending on how determinedly and efficiently we shall respond to this challenge, the Earth will have a second satellite, a man-made Moon circling the Earth at an altitude of slightly more than 1,000 miles in two hours. Assembled from prefabricated parts hauled into the orbit by huge, three-stage rocket ships of the weight of a light cruiser, this station will probably have the shape of a huge wheel of some 250 ft. in diameter. It will slowly rotate about its hub and its

80 to 100 inhabitants will live in the wheel's rim. A detailed outline of such a plan was presented in *Collier's*, dated March 22, 1952.

The station in space described therein will be the most fantastic laboratory ever devised. It will also be the springboard to man's further ventures into outer space, to the Moon and the nearer planets. But it will become a reality because of its tremendous potentialities as a deterrent of war. With its powerful telescopic cameras and radarscopes, the station's reconnaissance teams could take the most detailed pictures of any suspect area on the face of the globe at least once every 24 hours. They can thus pull up any Iron Curtain, no matter where it be. But while we may well hope that the station's mere existence would seriously discourage any large-scale military adventures, it has far greater potentialities. When it comes down to cases, the station is also a launching platform for orbital guided missiles against which there cannot well be counter measures.

What steps should be taken to establish a station in space and to build the rocket ships required for this purpose? Obviously, it would be utterly foolish to tackle the design and construction of a huge manned rocket ship without further ado and try to launch it to "destination orbit." The odds would be a hundred to one that any such attempt would result in complete disaster.

A step-by-step development approach is an absolute must for a project of such gigantic proportions. We need a plan, however, geared toward the ultimate goal, as we are taking the first faltering steps. This plan is an important thing. Many a serious rocket engineer, while firmly believing in the ultimate possibility of manned flight into outer space, is confident that space flight will somehow be the automatic result of all the efforts presently concentrated on development of guided missiles and supersonic airplanes. I do not share this optimism. While there is no question that such work will greatly contribute to the development of space flight, the ultimate conquest of space by man himself is a task of too great a magnitude ever to be a mere by-product of some other work. It requires a well-co-ordinated programme. Extending over a number of years, each step in this programme must dovetail with the previous and the next one.

The first thing we ought to do is to set up a study schedule which will take under advisement each and every phase of the problem. Such studies should not be limited to comparative preliminary design studies, but should include all aspects of military and scientific utility of a station in space. The verisimilitude of related problems in the fields of chemistry, radio engineering, structural engineering, aerodynamics, and guidance methods must be studied as well as the medical, radiological, biological and similar aspects. This first study phase can hardly be broad enough in scope. It should include investigations on the test facilities required for the development of rocket power plants, the logistic problems involved in manufacture, shipping and storage of the large quantities of propellants involved; training devices and simulators for crews and equipment; even the possibility of standardization of components should not be overlooked! Just think of the time and money for development work and test facilities that can be saved when we do reach the "hardware stage," if the rocket engines in the three stages of a large rocket ship could be standardized.

Prior to designing and building manned orbital rockets, it is surely good sense to develop relatively small, multi-stage rockets and fire them into an orbit, thus overcoming in miniature many of the practical problems which otherwise would beset the full-scale spaceship.

We may take some pretty long steps in our development programme without fear of being reckless.

Let us start with what we have to-day. On the basis of our present know-how and experience with supersonic airplanes we could start with the design of the third stage of our orbital ship and try it out like an airplane. With empty (or almost empty) tanks, it could be towed several thousand feet up and subjected to glide and landing tests by a test pilot. Fully tanked, it would then perform a vertical rocket take-off under its own power; its vertical flight could then be tiled into a horizontal path, out of which the ship could glide down and land. Such vertical take-offs would first perhaps be unmanned, the landing being performed by means of radio remote control; later on there would be a pilot in the cockpit.

Meanwhile, the second stage could be designed and subjected to careful ground testing. After having proven its reliability in extended static test runs, it would be flight-tested with a dummy third stage as payload—no first stage yet! Separation of the dummy and 'chute recovery of the second stage could thus be tested. Ultimately, the second stage would be used as a booster of an original third stage, thus enabling the latter to be flight-tested at higher speeds.

The large first stage would also be thoroughly developed and ground-tested in static runs. The development procedure is greatly facilitated by the fact that its mighty power plant (like those of the other two stages!) is composed of a great number of relatively small individual rocket motors and other components. The bulk of the ground testing can therefore be performed with individual motors, and only a few functional runs, perhaps with greatly reduced burning time, would be necessary with the complete power plant. (The development of the rocket power plants for the three stages is the most expensive single item in the development budget of a satellite rocket. As stated before, much money can be saved, if rocket motors, propellant pumps, valves and similar elements are reduced to a few standard types that may be used in several of the stages, before the actual design and testing begins.)

Development of its power plant completed, the first stage would then likewise be subjected to flight tests with dummy payloads, to the end of studying problems like the behaviour of the swivel motors in flight and to test the parachute recovery.

Only after all phases of such a development and testing programme have been completed could one dare readying the whole three-stage ship for its first manned flight into the orbit.

I have already mentioned that parallel to the programme just outlined, it appears expedient to fire much smaller, unmanned rockets into an orbit before we send people up there. Such experiments not only would have a tremendous technical and scientific value, but also would most certainly convince whatever doubting minds may be in control of the budget that a much more expensive manned satellite project is sound, too.

The development of a smaller, unmanned orbital rocket can be incorporated into the over-all project in such a manner that most of the critical parts and sub-assemblies can be used for both the small and the large rocket. A simple scheme to avoid duplication of effort and to save development work and money is this: take a rocket of the dimensions of the V.2 or the "Viking" (perhaps even a presently existing type), and call it the third stage of an "unmanned satellite vehicle." Now develop a *second* stage for this *unmanned* vehicle which has the same power plant as will be used later in the *third* stage of the *manned* satellite ship. Then select for the first stage of the *unmanned* rocket the same thrust rating as was wanted for the *second* stage of the *manned* version. By the time the development of the unmanned satellite rocket is completed, one then possesses already the power plants for the two upper stages of a manned ship, and the only power plant development further required would be the one for the large ship's first stage (which, however, may be composed of individual units already used in the second stage).

The scheme, sketchy as it may be, shows not only how effort and money can be saved in developing a satellite rocket, but it also proves the paramount importance of a well-planned strategy for the conquest of space. There should be a planning board, consisting perhaps of a propellant chemist, a rocket power plant designer, a test pilot with supersonic experience, an airplane designer, a flight surgeon, a radiologist, an astronomer, a navigation expert, a military planner, a federal administrator, a specialist on fuel logistics, and a few others. This board should study the general approach and map the over-all strategy. It would not need a large amount of money to get the wheels rolling—a few million dollars would do. But such a study will easily save billions later on.

The station in space will be the springboard for further voyages into space, and our obvious next goal would be the Moon. The first trip to the Moon will not involve a landing thereon. It will rather be a trip around the Moon which will enable the ship's crew to take—for the first time—a glimpse at the unknown other side of the Moon. But man's exploring urge will not rest before the first explorers have actually set foot upon the Moon's surface.

An actual flight to the Moon will probably not be carried out by a half-dozen explorers. It will rather be a full-fledged expedition, equipped with camping facilities, ground vehicles and elaborate research gear.

A DOWN-TO-EARTH VIEW OF SPACE FLIGHT

By Milton W. Rosen

(*Director, Viking Rocket Project, Naval Research Laboratory, Washington, 25, D.C.*)

In many respects, the rocket capital of the United States is White Sands Proving Ground, New Mexico. Here, in the 40-mile wide basin between the San Andres and Sacramento Mountains, rocket vehicles designed and built in widely different parts of the country are tested and fired. This is where the Viking established a record altitude for single-stage rockets of 136 miles and where the two-stage Bumper WAC ascended 250 miles, the highest altitude reached by a man-made vehicle. There is a saying among the rocket technicians

who meet and discuss their work at White Sands—a phrase which goes like this, "You have either just had trouble, or you are now having trouble, or you are about to have trouble!" A few successful flights have received wide publicity; the public seldom learns about the many rockets which do not fulfil predictions. Nor is it explained that great odds were overcome to produce a record flight—a flight that would have been nullified by the failure of one component in several thousand. In a rocket—everything must work. It is because I have spent much of the last six years at White Sands that I have such a down-to-earth attitude toward space travel.

Why is it so difficult to go much higher than we have been? It is because the engineers have caught up with the scientists. It is because they have almost exhausted our store of basic knowledge. The time lag between the discovery of a new material, technique or principle and its utilization has become increasingly short. The public has come to expect a constant flow of products each more wonderful than its predecessor. But the engineer who has drawn the ingredients from the cupboard of basic research now finds that the cupboard is bare. He must wait for new ingredients.

This is why plans for space travel and designs for spaceships are based on a meagre store of scientific knowledge, and a large amount of speculation. Now there is a place for speculation—if it is clearly labelled as speculation, and if its purpose is to stimulate interest in the subject. But I can hardly conceive of anything that would do more harm to this country's defence effort, and to the cause of space flight itself, than for the United States to undertake any one of the fantastic projects for a space ship that have been proposed in the last few years.

We can illustrate the difference between the speculative and the scientific approaches to space travel by imagining two scientists, whom we shall call "Scientist A" and "Scientist B." Scientist A is holding up a ladder which extends far into the sky. A typical American whom we shall call "Taxpayer" approaches and engages him in conversation.

Taxpayer: "What are you doing with that ladder?"

Scientist A: "Do you see that light high in the sky—that light is called space travel and I intend to climb this ladder and to reach that light."

Taxpayer: "I notice that many of the rungs are missing from your ladder."

Scientist A: "Don't worry about that—I will supply the missing rungs as I climb."

Taxpayer: "But how will you balance yourself on the ladder?"

Scientist A: "I will climb so fast that I will reach the top before the ladder topples. Then I will hang from the light and I won't need the ladder any more."

Taxpayer: "Well, let's see you climb it."

Scientist A: "I forgot to tell you—I need ten billion dollars before I can start."

And before Scientist A can finish that sentence, the taxpayer has disappeared. Now we see Scientist B, who is building an immense pyramid block

by block. Construction is not far advanced—the highest block is only a few yards above the ground. The taxpayer approaches.

Taxpayer: "What are you doing?"

Scientist B: "Do you see that light . . .?"

Taxpayer: "Your friend, Scientist A, told me about it. Are you trying to reach it? Is that why you're building the pyramid?"

Scientist B: "Yes—and it's very hard work. Sometimes I have to search all day to find one block—and when I need one of a particular size and shape, it may take weeks or months to find it."

Taxpayer: "Are you going to ask me for ten billion dollars?"

Scientist B: "Heavens no! I wouldn't know what to do with that much money. But I could use a few million dollars for modern equipment. You see—as the pyramid grows higher, it becomes increasingly difficult to lift the blocks."

Taxpayer: "I can't see any return for that investment. Your progress is too slow. I will be gone and forgotten before you get close to space travel. But don't be discouraged. If you ever get to the place where you need only a dozen more blocks, I will buy that dozen!"

Where do we stand to-day with respect to space travel? To answer this question let us consider the feasibility of building a manned, earth-returnable rocket on the basis of what we have done, rather than what we think we can do. A manned earth-returnable rocket is a vehicle which travels some distance away from the surface of the Earth, which carries one or more human beings as passengers, and which includes provisions for ensuring the safe return to the Earth's surface of these passengers. It is not considered essential that the vehicle itself return in a re-usable form.

Altitude is the primary factor in any consideration of the feasibility of a manned, earth-returnable rocket. Two altitudes, 15 miles and 50 miles, are significant because they define the boundaries of three regions that can be considered separately. These are the regions between the ground and 15 miles where feasibility has been demonstrated, the region between 15 and 50 miles wherein feasibility can be shown, and the region above 50 miles where a decision on feasibility is not possible to-day.

According to recent unofficial, but reliable reports, a Douglas Skyrocket has reached an altitude of 15 miles and its pilot has returned safely to the Earth's surface. For an altitude of 15 miles, then, feasibility has been demonstrated. No more needs to be said.

Feasibility can be shown for a manned earth-returnable rocket that reaches an altitude of between 15 and 50 miles, even though no human has ever reached these heights. Rockets have been built which can ascend 50 miles and which can carry the necessary payload involved in transporting a human being. The significance of the 50-mile height is that parachute recovery has been successful below this altitude. Entire WAC Corporal rockets and instrument sections from Aerobees have been recovered by parachute from altitudes up to 50 miles. The accelerations encountered on the powered ascent are within the tolerance

limit of human beings. The maximum velocity is sufficiently low that, for a vertical ascent, the vehicle skin temperature will not tax the capacity of known materials and techniques of construction. The most important feature of a flight to less than 50 miles is that the duration of flight will be brief—a matter of several minutes. For this reason, many of the difficult problems that would be involved in flights to higher altitudes will be ignored when the altitude limit is only 50 miles. These problems include the effects on the vehicle and its passenger of cosmic and solar radiation, meteor collisions and free fall in a vacuum. Because the flight time is so short, it will not be necessary to make elaborate provision for the necessities of life: food, oxygen, elimination of wastes and maintenance of ambient temperature. The most important problem in this region is one of reliability.

In considering the feasibility of building a manned, earth-returnable rocket for altitudes between 15 and 50 miles, the important words are *man* and *return*. The reliability of the vehicle must be weighed against the man's chance for survival. This concept of reliability must enter into the design of every component, sub-assembly and operating system of the vehicle. The factors of safety here are entirely different from those presently used in the design of sounding rockets. The probability of returning a man safely 99 times out of 100 is a very much smaller number than the probability of a safe return 1 time in 100. For the region between 15 and 50 miles, then, the important question to be answered is not whether a manned rocket can reach the required altitude, but whether the same man can make two flights.

Above 50 miles the situation is entirely different. Attempts at parachute recovery of instruments have not been successful. Depending upon the altitude to be reached, the accelerations could be beyond human tolerance limits and vehicle skin temperatures above the melting points of available materials. The Viking rocket, which reached an altitude of 136 miles, could have carried a man, but no one could have ensured his safe return—no one could have calculated the probability of his survival. If the duration of flight is sufficiently long, the effects of cosmic and solar radiation must be considered. The nature and quantity of these radiations in outer space have not been fully determined, and we are only beginning to study their effects on living cells. The probability of meteor collisions has been estimated and various schemes for eliminating this hazard have been proposed, but have never been tested. It is not possible to predict the physiological and psychological effects on a human being of a prolonged weightless state. If the flight time is long, as it will be when we speak of very high-altitude rockets, satellites, and space ships, elaborate equipment will be required to provide the human being with the necessities of life. A continuous power source will be needed for the operation of such equipment. Since the flight may impose terrific physical and psychological strains on the passenger, it is expected that all equipment necessary to power and guide the vehicle, to provide the necessities of life, and to ensure the passenger's safe return will have to be automatic in operation. Feasibility will have to be shown for every one of these machines—machines which will have to perform a diversity of functions with great precision. A tremendous amount of investigation, measurement and test will have to be conducted

before one can assess the magnitude or importance of most of the problems involved. The discussion for altitudes above 50 miles leads to the inevitable conclusion that, at the present time, we cannot even estimate the feasibility of building a successful manned rocket, because of insufficient information.

If we cannot build a spaceship to-day, what can we do to advance the cause of space travel? We can do much—we can discover the ingredients for future engineering—we can replenish the cupboard of basic research. Before we can attempt to transport human beings in a ship that orbits around the Earth, we must produce a practical, reliable, unmanned satellite. To do this we need better, more efficient, rocket power plants, and our progress in recent years has been slow. Anyone who can operate a few machine tools can build a rocket motor and make it work. It is one of the simplest engines for converting chemical energy into mechanical energy. But no one fully understands the theory of combustion in a rocket motor. This is one reason why every rocket manufacturer in the country is having difficulty in improving his product. We need more research on fuels, on high-temperature metals and ceramics, on novel methods for cooling the inner walls of rocket motors and the outer skins of high-speed airframes.

Atomic energy has been envisioned as an almost limitless power source for the propulsion of a rocket. The application is important, but its value has been over-estimated. Some limitations of present-day rockets still apply. There is a practical limit on the temperature at which a rocket motor can operate and it matters little whether the heat has been generated by nuclear or molecular reactions. All rockets are propelled by the ejection of matter and our atomic rocket will have to carry a working fluid. This fluid can have lower molecular weight than the exhaust gases of a chemical combustion and herein lies the major gain to be achieved from the use of a nuclear power plant. The protection of instruments and personnel against damaging radiation is an obstacle to be overcome. Despite these difficulties, the potential use of nuclear power for the propulsion of rockets cannot be ignored. It remains to investigate the use of nuclear rocket power in the laboratory and in the test pit, before we construct the first atomic-powered rocket vehicle.

Hand in hand with rocket power gains must come progress in the field of electronics. The navigation of a spaceship, communication between the ship and Earth, and automatic control of the complex equipment necessary for human survival in outer space—all pose tremendous problems for the electronic scientist.

I will not attempt to list or classify the many investigations that evolve from our desire to send a human being into outer space—research that falls into the category of human engineering. Many of the problems and a few of the answers have been ably presented by Dr. Haber. This type of research can proceed, in fact, must proceed concurrently with vehicle development if we contemplate human travel in outer space. Herein lies many years of research for the biologist, physiologist and psychologist. When asked what fields of scientific endeavour are embraced by the subject of space travel, a co-worker of mine replied, "It would be easier to name the fields that are not required." When pressed further he was unable to name any field of science that could be eliminated categorically.

Finally, we need more and better sounding rockets—rockets which can ascend far above the pedestrian altitudes thus far achieved. Sounding rockets are our best laboratories for space-flight research. They are, indeed, the predecessors of future spaceships, but they are the remote—not the immediate ancestors.

Thus far, research contributing to space travel has been accomplished as a by-product of other projects—largely military. A better rocket motor is a better rocket motor—whether it is intended for a guided missile or a sounding rocket. Conversely, many investigations which further space travel have been supported because they also contribute to our national defence. The time has come, I believe, for some one or some group to assess clearly the problems involved in space flight and to determine what we are doing and what we could do to make further progress. Such a group should consist of able and respected representatives of government, science, and industry and could well be sponsored by the National Science Foundation recently created by Congress.

I would commend to the group the following procedure:

(1) They should make a thorough study of existing knowledge on space flight and then prepare a list of the problems which must be solved before it can be achieved. Such a list will be lengthy and far from complete.

(2) They should select from the list, those problems which can be tackled with the techniques and tools available to-day.

(3) They should examine every project in the country which is closely allied to the field of space flight. Many of these projects are classified for security reasons and could be revealed only to a select group.

(4) They should recommend to government and industry, present and future support for those projects which are making a worthwhile contribution to space flight.

(5) They should recommend the initiation, when appropriate, of investigations which are not being conducted and which could yield important results in the near future.

A large share of our scientific talent is now enlisted in the effort to resist and deter foreign aggression. We can, I hope, look forward to the time when some of this talent can be released from the task which is so urgent to-day. The recommendations of the proposed space-flight committee would constitute a programme that could be implemented when the country can afford the manpower and money required to support the work.

Now comes the question—why do it at all? This country should not and, I feel confident, cannot be frightened into attempting space flight before it is technically feasible. The alleged military value of a spaceship is as speculative as to-day's spaceship designs. Also we can only speculate about the material benefits that might be derived from the exploration of outer space.

I am reminded of Aesop's Fable about the farmer and his sons. A farmer, being on the point of death and wishing to show his sons a way to success, called them to him and said, "My children, I am now departing from this life; but all I have to leave you, you will find in the vineyard."

The sons, supposing that he referred to some hidden treasure, went to work with their spades and ploughs as soon as he died, and turned up the soil over and over again. They found, indeed, no treasure; but this thorough tillage yielded a finer vintage than they had ever reaped before and more than repaid the young husbandmen for all their trouble.

Similarly with space travel; the knowledge we will have to gain, the techniques we will have to master, the machines we will have to build—will bring more material benefit to the Earth's population than any gold or uranium we may find on Mars or Venus. The value of space flight is in the doing of it.

HUMAN FLIGHT AT THE LIMITS OF THE ATMOSPHERE

By Fritz Haber, D.Eng.

(*Department of Space Medicine, U.S.A.F. School of Aviation Medicine, Randolph Field, Texas.*)

What really is the weight of a body and how can it be determined? It is this question that we have been asked many times in the Department of Space Medicine. There are many possible and correct answers, but one—in our opinion—is the clearest one. This answer is that the weight of a body is equal to the force of its support, and is independent of the force of gravity. This explanation is especially suited for analysing the weight of an entire system such as an airplane, a rocket or a spaceship. The only fact to be considered is the supporting force which includes all external forces acting on the body. The sum of all these forces is then equal to the weight of the body.

In all cases of weightlessness the identification of weight with support becomes exceptionally clear if a body is left without any support whatsoever, then we can state immediately that this body is without weight. This is true everywhere, independent of the existence of a gravitational field; it is also true right here in this room. This statement can be proven by a simple experiment.

(*Demonstrated by a slow-motion film sequence.*)

Take a bottle partly filled with water, seal it, shake and mix the contents; the air and water inside the bottle will separate very quickly, just as soon as we stop shaking the bottle, due to the difference in weight of water and air. In a state of weightlessness, however, this separation does not take place because water and air do not have a different weight, that is, they both have no weight. We can now render the bottle weightless by depriving it of its support—that is, by allowing it to fall. During the fall we can then see that the water and air do not separate but stay mixed. This is proof that the state of weightlessness is possible even in a gravitational field. It is also proof that the weight is equal to the supporting force.

Rockets and spaceships are designed to vary the force of their support and therefore their weight. Speaking in somewhat a sophisticated manner, we could reduce the idea of a spaceship to the statement that a spaceship must be capable of varying and controlling its support in any desired fashion.

The human body in a prone position can tolerate an elevenfold increase of

its weight for 2 to 3 minutes and in supine* position fourteenfold increase for the same time. Breathing becomes very difficult under increased weight due to the tremendous weight of the parts of the chest, which must be moved for the purpose of respiration. The values quoted were obtained in experiments with a constant acceleration. In a rocket take-off, however, the acceleration and likewise the weight is not constant but increases toward the end of the propulsion period. To tolerate an increased weight is always a very unpleasant experience, but to know that it will become worse as time goes on adds a psychological factor. Engineer and doctor should co-operate on this point in order to achieve the highest performance of man and machine.

It is completely unknown what a prolonged state of weightlessness does to the human body. We can rule out any severe disturbances of circulation, but should expect some trouble in orientation and muscular co-ordination. The entire system of reflexes which controls orientation and motion of our body will be upset. It is very likely that the future space pilot will adapt himself to this new environment. He must learn to disregard some information as furnished by his senses and to evaluate others in a different manner. A new set of reflexes must be developed. This is similar to the process one undergoes in learning to ride a bicycle, to drive a car, to fly an airplane, or more especially to fly blind on instruments. The first experience of being in a prolonged state of weightlessness might be disturbing. There might also be some difficulties during sleep, when the mind no longer is alert enough to ward off the deep-rooted sensations of falling, which are associated with the weightless state. But man has a wide range of adaptive abilities and there is a high probability that he will overcome the eventual difficulties. This will take some time, of course, but just how much is not known.

The V.2 rocket is in a state of weightlessness for about 4–5 minutes. So far this is the longest period of zero weight ever achieved. Some experiments with animals have been carried out by Henry and co-workers of the U.S.A.F. Aeromedical Laboratory in Wright Field by using an Aerobee rocket which provides a somewhat shorter time of weightlessness. The experiments were designed to prove whether or not any circulatory changes would occur. It was shown that other than some insignificant changes in the activity of circulation, nothing serious happened. For obvious reasons no evidence of disturbances in orientation could be obtained from animals. This field must be investigated with human subjects.

There are more occasions in rocket and space-flight involving variation of weight. For example, there is the famous proposal of Dr. Sänger to accelerate a rocket with wings to high speed and high altitudes. After burn-out the rocket would return into the denser layers of the atmosphere, where enough lift can be provided by the wings to pull out of the atmosphere again. The method is about the same as that of skipping a flat stone over the surface of water.

It is obvious that in such a pullout the weight will be much greater than the normal weight. Therefore, periods of weightlessness will be followed by periods of superweight. It is very likely that for this reason such a trip will not be a

* Prone is lying face-downwards, supine is lying on the back.

pleasure trip. One must pay with superweight for the pleasure of weightlessness. This is not only a simple phrase, but rather a real law of physics.

A body in a motion going straight up and down in the gravitational field of the Earth must have an average weight during the time of the motion, which is exactly equal to the normal weight. For example, a period of weightlessness lasting 10 seconds must be compensated by a period of an elevenfold weight lasting 1 second, in order to obtain the normal weight as average. The relations are a little more complicated in a circular motion around the Earth, but in principle a similar reasoning can be applied resulting in certain statements concerning the trajectory of Sänger's round-the-world rocket. If it is manned, then for reasons of human tolerance the weight during the pull-out should not exceed a certain value. For the purpose of this discussion let us put this value at six times the normal weight. Now, if the first period of weightlessness lasts 15 minutes, then the sixfold weight must last slightly over 2 minutes. Therefore, this simple law of the average weight can be used to show how periods of subweight must be followed by periods of superweight and how their duration is determined.

SOLAR SYSTEM NOTES—6

By Patrick Moore, F.R.A.S.

During the last few months of 1952, Jupiter still dominated the night-sky, shining down with a brilliance surpassing that of any other planet except Venus. It is larger than the rest of the planets put together, and despite its great distance—it never comes much closer than 400,000,000 miles—it appears to us a splendid orb.

Although Jupiter has four large satellites, and it is these which will probably be utilized as bases in the far future, it is of interest to find out as much as possible about the planet itself, and recent observations made in Britain and America indicate that present conditions there are far from normal.

Jupiter is not solid throughout its mass. Jeffreys and Wildt consider that it consists of a rocky core about 44,000 miles in diameter, surrounded by a thick layer of ice, which is in turn overlaid by a deep, dense "atmosphere" in which methane and ammonia predominate; and whether this picture is entirely accurate or not, there can be no doubt that the visible surface of Jupiter is gaseous in nature. As in the case of the Sun, the axial rotation period is not constant throughout the globe. At the Jovian equator, the "day" is about 9 hr. 50 min. in length, but at the poles it is several minutes longer, which is positive proof that we are not dealing with a solid surface.

The markings on Jupiter are distinctive, consisting of well-defined bands or "belts" and various bright and dark spots. They are not permanent, and shift and change from week to week. Now and again there are outbreaks of violent activity, as occurred in the southern equatorial belt in 1949; at other times the surface is comparatively quiescent. There is, however, one feature which appears to be semi-permanent, or at least very long-lived. This is the "Great Red Spot." When it first became prominent, in 1878, it was described as a reddish-pink oval area, lying well south of the tropical zone, and investigations

revealed that it could be traced on drawings made as far back as 1664. It is no longer very conspicuous, but can easily be identified; it drifts about to some extent, and its rotation period is slightly variable.

It has, however, lost most of its colour, and this applies also to other surface features. Thirty years ago, the hues of the belts were intense—some brown, others strongly reddish; to-day the hues are faint and fugitive, and it is not easy to explain the change. It is probable that the belts are the same colour as before, but temporarily veiled by Jupiter's upper atmosphere (as has been suggested by Dr. Steavenson). During the present opposition, the writer, using a 12½ in. reflector, has been unable to see any definite colour at all, and there are other signs that surface conditions are abnormal. Most of the belts are strangely faint and ill-defined, and spots and disturbances few and far between.

Similar conditions have been noted in the past from time to time, and have usually been followed by sudden outbreaks of violent activity, so that Jovian observers are expecting interesting developments during the next year or so. The underlying causes of these variations are most uncertain. We have to confess that there is much we do not know about the Giant Planet, but careful and continuous observations may solve at least some of its mysteries. Although it seems unlikely that space-craft will actually land there, it is obviously important for us to find out as much as we can.

BRANCH MEETINGS

London Film Show, April 11, 1953

The Society's presentation copy of "Destination Moon" will be screened on April 11, 1953, at the Lecture Theatre of the Science Museum, Exhibition Road, South Kensington, S.W.7, by courtesy of the Director.

This film show is *open to members of the Society only*, and application for tickets should be addressed to the Secretary now, *enclosing a stamped addressed envelope for reply*.

To meet the convenience of members, two performances have been arranged, at 10.45 a.m. and 6 p.m. respectively, and although every effort will be made to accommodate those who wish to attend a particular showing, it would be appreciated if members would indicate if either time would be suitable.

Bristol Meetings

The meeting of the Bristol group held on November 8, 1951, was very successful, about 41 members and guests being present.

This was followed by a further talk on December 6, 1952, when F. A. Smith gave a paper on "The Moon," illustrated by a number of slides.

Further lectures arranged for this session are as follows:

1953.

Feb. 7—"Introduction to the Rocket Motor," by R. K. Taylor.

Mar. 7—"The Planets," by W. R. Clark.

April 11—"Film Show."

It should be noted that the date of the April meeting has been changed to that shown above, owing to the incidence of the Easter holidays.

The Group Secretary is P. W. Stone, 18, Elm Park, Filton, Bristol, from whom further particulars about activities of the group may be obtained.

B.I.S. Meetings at Coventry and Leicester

The Midlands Branch are holding an additional Branch Meeting at the College of Technology, Coventry, at 6.30 p.m. on Saturday, January 24, 1953, when the Branch chairman, Mr. N. R. Nicoll, will give a talk on "The Present Position of Astronautics."

This meeting is designed to bring members in the Coventry area in touch with each other and with the Branch, to find out the possibilities of holding further meetings in Coventry, and to stimulate public interest in the area.

The talk will be repeated at the College of Technology, Leicester, for the convenience of local members on Saturday, February 28, 1953, at 6.30 p.m.

Midlands Branch Meeting, October 11, 1952

The second meeting of the Midlands, 1952–3 lecture session was held at the College of Technology, Birmingham, 1, when E. Burgess, F.R.A.S., presented a paper entitled "The First Moon Rocket."

The paper gave an outline of the vast magnitude of the task of preparing and launching the first lunar expedition, the main problems involved, and some possible solutions to these problems. A description of the lunar surface and conditions was given, and the steps which would be taken to ensure the success of the expedition, in spite of these conditions, were indicated.

Seventy-six members and visitors were present.

Meetings of the Provisional Yorkshire Branch

The first meeting of the provisional Yorkshire Branch was held at the College of Technology, Leeds, on Saturday, November 8, 1952, when 41 members and visitors attended.

Mr. M. S. Wright (Branch Secretary) took the chair, and introduced Mr. A. Clementson (Blackburn and General Aircraft Co.) who gave a paper entitled, "An Introduction to Astronautics."

Mr. Clementson began by enumerating the existing branches of knowledge which make a contribution to astronautics, and showed how all were integrated in the new science.

He then mentioned some early ideas about the realization of space-flight, and explained how these had been modified in the light of later discoveries. He developed this up to the present day, and briefly mentioned some of the most modern proposals on the subject.

The main part of the paper consisted of an analysis of the problems of space-flight, with particular reference to aeronautical aspects and the problem of power plants. The paper also dealt briefly with some of the physiological questions, and concluded with a discussion on how space-flight would prove of benefit to mankind.

On January 17, 1953, our Chairman, Mr. A. C. Clarke, will give a lecture entitled "The Exploration of Space," at the Y.M.C.A., Leeds, beginning at 3 p.m.

BOOKS AND PERIODICALS on astronautics bought and sold.—Astronautica, 31, Brooklands Gardens, Hornchurch, Essex.

NOTES AND NEWS

Life on Other Planets

On September 9, 1952, the B.B.C. broadcast an excellent programme on the above subject, devoting no less than 45 minutes of Home Service time to it. The authors (D. F. Aitken and John Harries) showed a thorough familiarity with the evidence, and the programme took the form of a discussion between a group of somewhat acidulous dons in a Senior Common Room. After the usual arguments had been well aired, it was finally decided that the only way to settle the matter was to go there and see. . . .

Spaceflight Television Programme

Under the sponsorship of the Johns Hopkins Science Review, a series of half-hour programmes entitled "How Man Will Conquer Space Soon" is appearing on C.B.S. TV in America. Using models, diagrams, charts, films and the like, the programmes present the subject in simplified form to the average televiewer. The first programme dealt with the step-rocket and its development, and what is needed in order to escape from this planet. In the second, Dr. von Braun discussed the space-station, and in the third Willy Ley considered the lunar voyage.

Willy Ley has also been making a weekly appearance on radio with the A.B.C. network, answering questions on astronautics.

From the World's Press

The following editorial from the London *Star* of July 31, 1952, is reproduced without comment:—

"After much public debate because jet fighters were not sent up to chase the latest crop of 'flying saucers' the United States Air Force has poured cold air on the critics.

Its experts say that what was seen on radar screens was no more than layers of cold atmosphere sandwiched between hot ones during recent meteorological disturbances.

But if the saucers are really to end up as myths interest in interplanetary flight—and belief in its possibility—is unlikely to decline.

Mr. Arthur C. Clarke, Chairman of the British Interplanetary Society, has said that a century hence we—or rather our grandchildren—should be flying to Mars in space-craft which may travel at 100,000 miles an hour, and will probably be shaped like dumb-bells.

Man's yearning to see what exists outside this globe dates back to pre-historic times. But nowadays it is as real and urgent as the urge to fly was in the days of the Wright Brothers.

Rocket propulsion, first perfected for war purposes, has given an enormous impulse to this zest for 'new worlds to conquer' in the most literal sense.

Boys lap up space-flight stories as avidly as their fathers absorbed Westerns. The difference is that this kind of romantic escape fiction looks forward, where the other glanced back to a past age of adventure.

Those who deride these scientific ambitions seem to be related to the elders of yesteryear who said that 'if God had meant man to fly He would have given him wings.'

At any rate if rocket flying is to be diverted from carrying atom bombs to exploring the Universe everyone should welcome the change of direction."

* * * *

In their editorial for June 6, *The Aeroplane* commented on the apparent slow rate of progress of British rocketry, at least as revealed by the lack of news released to the Press; mentioning the speech of the Minister of Supply

when he opened the Ashorne Hill guided weapons conference on May 20, they said: "From (his) use of the word 'advent' we have to assume that guided rockets are yet to come, so it seems that however remarkable the progress which has been made, it has not been enough to give us any rockets."

Commenting further that "the guided missile of to-day is the germ of to-morrow's public transport," *The Aeroplane* went on to say: "The fact that at the moment official research is being concentrated on missiles must not blind us to the coming use of such transporting devices for carrying passengers as well as goods. Thank goodness for the existence of the British Interplanetary Society; they at least provide a signpost for their fellow-countrymen as to the way aerial transport is developing."

Well! We blush—but *thank you*, Mr. Thurstan James, thank you very much indeed. Would it be possible to change the name of your paper to *The Aeroplane and Spaceship*? As a first step, that is, towards altering it eventually to *The Spaceship and Aeroplane*. (N.B.—*Mr. Thurstan James is not (yet) a member of the B.I.S.*—ED.)

* * * *

The American press has carried many very favourable reviews of our Chairman's book-of-the-month, *The Exploration of Space*. We liked the *New York Times* one that began by saying that space ships ". . . will simply be new embodiments of man's peculiarly and magnificently tenacious determination to venture in to the unknown," but even better one from *The N.Y. World Telegram and Sun*. This said of the author: "He is not to be confused with the utterly irresponsible 'comic book' dope-peddlers helping to induce a sort of juvenile schizophrenia all over the semi-literate world."

Which reminds us—we were shown a recent editorial from *Amazing Stories* which revealed that some, at any rate, of the science fiction boys are nothing better than a miserable, pathetic, collection of wishful-thinking heretics. We *were* amazed—by the heresy part, anyhow. Listen (we quote):—

> "*Homo sapiens* will never get into a space ship and roam the void. First, there is no place to go; second, 'no place' is so far away man couldn't live to get there and no conceivable combination of metal and power would stand up under the punishment of getting him there.
>
> "Cities built by man upon the Moon? Absurd . . . on the sun-side of the Moon a man would fry to a crisp. On the dark side he'd need so much equipment to keep from freezing to death, he couldn't move . . . (meteors) large and small would knock out a squad of Sherman tanks before they had travelled a mile (on the Lunar surface).
>
> "So that's that. Cold fact says no to all our dreams . . . (but) we get sick of fact. . . . We know none of this could happen, but *just suppose* there *is* a beautiful maiden waiting on Mars to be rescued. For heaven's sake, let's get up there and rescue her!
>
> "The world of dreams. A priceless world given us by a kindly Creator who knew the going would get tough at times; who knew there would be cold dreary facts to burn on this tired old planet and that we would need moments of blessed escape."

Hence, we read, a few paragraphs from the end of this Amazing Story: "Mary and Joe Dokes . . . sneak off into the fairy world of romance, adventure, action . . . (and) buy (*How did you guess?*!—ED.) *Amazing Stories.*"

Well, all we can say by way of comment is that some of these science-fiction fairies are going to get an awful surprise if they are still around a generation or so hence. They'll find some other dreamers dreamed the same dreams—but worked to make them come true.

* * * *

The New York Times recently speculated facetiously that current Soviet interest in theories of planetary formation, and other celestial phenomena, stemmed from their having noticed that the rest of the world was full of discussions of "artificial satellites"—in view of the Russian technique of gathering political satellites around their country, what more natural than that they should want to be in on this business of satellites in outer space? "From such a (space station), Soviet observers could keep in close touch with the red planet, Mars. . . ."

At least one ex-patriate Russian—Major Alexander P. de Seversky, the aviation writer who used to design some very good fast aeroplanes (he founded what is now the Republic Co.)—is certainly showing an interest in space flight. In recent articles he has predicted orbital rockets "within the lifetime of most of you who read these lines," and lunar space ships soon afterwards.

* * * *

A news release from the Society of British Aircraft Constructors just before their Farnborough show dealt with the growing importance of rocket missiles and rocket motors, and was widely quoted in the papers. At the Show itself, there were several items of rocket interest. "Snarler" and "Sprite" motors were shown respectively on the Siddeley and de Havilland stands; the former also featured an impressive diagrammatic model, complete with coloured lights, of a turbo-pump fed aircraft rocket motor. "Sprite" rockets were demonstrated as a means for take-off assistance on a "Comet," giving an almost invisible efflux which indicated the use of some other catalyst than permanganate. In the aircraft static display, there was a rocket-propelled, delta-winged, research model of Fairey's; its power unit appeared similar to the twin-chambered design shown previously as the "Beta I" by the M.o.S. This year, the Ministry exhibits included a very neat single chamber motor called the "Beta II"; its size suggested a similar use, for the propulsion of research models. On the same official stand, examples of special seals and pumps, etc., developed for rocket motors, and a small test missile, were also shown. The Bristol stand included a ramjet test vehicle, with rocket boost for take-off.

A liquid-propellant rocket test vehicle, with solid booster rockets, was also shown a few weeks earlier at the Earl's Court Radio Exhibition, again on an M.o.S. stand, as an illustration of the importance of the radio industry in missile guidance techniques.

Joseph McNarney, a retired U.S.A.F. General, who is now President of the Consolidated-Vultee Aircraft Corporation (builders of the B.36 and B.60 inter-continental bombers, and several missiles), said in San Diego on June 2 that the merger of the guided missile and the aeroplane was not far distant. He was opening a new $3,000,000 research facility for his company at the time, and added: "When that day arrives, the building of interplanetary craft and the so-called satellite aircraft will have become entirely practical and feasible," also that Convair's work on an atomic-powered plane "was progressing satisfactorily."

* * * *

On June 15, the big Indian newspaper, *The Hindu*, published a review of Sir Charles Darwin's new book, *The Next Million Years*. The reviewer was Frederick Grubb, London correspondent of *The Hindu* from 1911 to 1934, and now 83 years old; he took, we were glad to see, a rather less gloomy view of mankind's future than Darwin, and said: "Is it fanciful to predict that, within a conceivable future, men (and women, too) will . . . be reaching out into depths of space which now seem fathomless? . . . who can measure the effect of the resulting discoveries even upon our mundane problems of population? . . . will not other worlds be open to peaceful conquest before this old Earth is exhausted? . . . Pushful investigators have already ventured into and beyond the stratosphere, and it begins to be certain that contact with outer space promises something more than a Jules Verne 'voyage to the Moon'." It was, we feel, just this sort of thinking that the grandson of the great Charles Darwin left out of his recently much-quoted calculations.

* * * *

Various papers, ranging from *Time* to the *Glasgow Observer*, quoted at length during August some extraordinary pronouncements by Fr. Francis Connell, Dean of the School of Sacred Theology at Washington Catholic University. This learned theologian discounts the theory that flying saucers are visiting spaceships, but does not rule out the possibility that God might have created rational beings on other worlds, and even that some of these might be "intellectually superior" to Man, and capable of mastering interplanetary travel. It appears that such extra-terrestrials might not share Man's "state of grace" (?); alternatively, they might still be in the state of innocence of Adam and Eve, never having suffered the Fall. Various earlier Catholic writers on this subject were invoked, in support of his views, by Fr. Connell, who gave a positively mediaeval list of the limiting conditions under which God could have created Martians *et al.* Frankly, we do not pretend to have even begun to understand this, but a lot of it seems to have to do with angels, devils, and possible actions of the various Persons of the Holy Trinity on various planets.

It appears that there is a whole section of the interplanetary literature unknown to us, or even to any other writers on the subject, with the possible exception of C. S. Lewis. It would also appear, however, that different readers can come to different conclusions, even if they are Catholic theologians: in the

Glasgow Sunday Mail of September 14, we found a statement from "Professor Agostino Gemelli, President of the Papal Academy of Science, who revealed that he was a committee-member of a Vatican-sponsored society with the object of promoting flights into space." This news took our breath away, but reading on, we found the following, even more interesting, item—appropriately enough, under the sub-heading "Fantastic": "Attacking American churchmen's recent reasoning, Professor Gemelli said his uncompromising denial of the possibility of human beings inhabiting other planets was based on the Old and New Testaments. Neither contained the slightest reference to other human worlds, but made it most clear that God had chosen the Earth alone as living place for man."

* * * *

About the middle of August, an altogether disproportionate attention was paid by the British Press to some tests carried out in Germany by Albert Pullenberg and others. The experiments in question purported to be in connection with the development of trans-Atlantic mail-carrying rockets, but actually they were carried out with small and crude, home-made, powder rockets. Unfortunately, they were responsible for some ill-informed comment about the risks of revived German rocket research, having been taken rather more seriously than they deserved!

* * * *

According to the *Sunday Express*, Yvonne de Carlo says she wants to marry the first man to fly to the moon—"because he could take me some place I've never been before." We commend this item to those seeking a new answer to the frequent question as to our motives for interplanetary travel.

* * * *

The month of August saw a great deal of astronautical newspaper activity in the Midlands, triggered off by leading members of the B.I.S. Branch in that region. The *Coventry Standard* dealt at some length with the Branch's design study for a space-rocket ("Project Caliban"), the *Birmingham Mail* published an article by Derek Lawden, and then opened its correspondence columns to him and Mr. Rotherham (Branch Secretary), so that they could deal with the many questioners and sceptics revealed amongst their readers. *Apropos* of which, we may say that we still expect to hear the statement that a rocket will not work in a vacuum made the day *after* the first landing on the Moon!

* * * *

Space-flight hás been breaking into British radio again: during July, Dr. Porter told listeners to his Light Programme talk, "Up Among the Stars," that "spaceships are now not just pipe-dreams." He went on to give a number of facts and figures . . . but (we hasten to add) . . . nothing like so many as an incredibly erudite butler called Coulson in a fictional Home Programme ("Life on Other Planets") broadcast early in September. This admirable Coulson gave his donnish masters the right answer to the question (i.e., is there any?) with which the feature dealt . . . wait until we get there to see for ourselves.

Early in the autumn, the London *Star* (and other syndicated provincial papers) ran a series of articles by Merrick Winn on "The Riddle of the Universe." Apart from a few astronomical "howlers," these were unexceptional but interesting enough; however, they did contain the flat statement (in large type, too!) that: "There has never really been a Man in the Moon, but there soon will be. . . . It will happen in the normal lifetime of everyone under 30."

About the same time, A. V. Cleaver in the *News-Chronicle* series, "World of To-morrow," predicted pioneer flights to the Moon, Mars and Venus by 2002 A.D.

The layman ought soon to accept this idea completely, by a process of constant re-iteration. All we have to do then is the job itself. ... .

* * * *

West Germany's Security Commissioner, Herr Hans Egidi, recently added yet another statement, to many previous ones from other sources, alleging that the Russians were firing experimental rockets out over the Baltic from the reconstructed research station at Peenemunde.

* * * *

The Rome meeting of the International Astronomical Union, during September, brought forth another Russian comment—this time on flying saucers, which (incidentally) the conference decided that it would not discuss officially. Professor Boris Kukarkin described them as "war-mongering psychosis," and added: "They are optical illusions of pure fantasy. What cannot be understood is why they are said to fly over all parts of the world with the sole exception of the Soviet Union, which is a nation of great extent."

* * * *

During September, the U.S. Air Force (after earlier unsuccessful attempts), succeeded in firing a monkey and two white mice aloft in a research rocket, *and* in recovering them safely, in a parachuted container, afterwards. We hope that many readers will have seen the brief but quite fascinating newsreel film, which showed one of the mice struggling helplessly, under free-fall conditions, during its flight. It was quite unharmed, but obviously unable to reach any position on the sides of its container, as it apparently wished to do; its companion remained securely on a small ledge all the time—no doubt watching the antics of the other mouse with superior amusement.

Errata

It is regretted that Mr. P. A. Start was incorrectly printed as "Mr. P. A. Stuart" in the list of members making donations of over 10s. on page 362 of the 1952 Annual Report.

The number of members of the Chicago Rocket Society shown on page 317 of the Annual Report as *"not known"* has now been notified to be 65.

The scale of Compounded Subscriptions shown on page 310 of the Annual Report was taken in error from that of the preceding year. The correct scale appeared on page 88 of the March, 1952, *Journal* and should be substituted for that shown in the Annual Report.

ABSTRACTS

Edited by J. HUMPHRIES

Abbreviations of titles of journals were given in the May, 1950, issue of the *Journal*, and addenda have appeared in subsequent issues. The following is a further addendum to the list.

Hawker Siddeley Rev.	Hawker Siddeley Review.
Nat. Bur. Stand. Tech. News Bull.	National Bureau of Standards Technical News Bulletin.
Riv. Aero.	Rivista Aeronautica.
Z. Phys. Chem.	Zeitschrift für den Physikalische Chemie.

Many of the articles noted are available on loan to members resident in the British Isles. Requests should be addressed to J. Humphries, 97, Churchill Avenue, Southcourt, Aylesbury, Bucks.

AERODYNAMICS

(1) **The aerodynamics of guided missiles.** P. W. POWERS. *Antiaircr. J.*, **95**, (4), 12-14 (*July-Aug.*, 1952).
Introduction to the principles.

AIRCRAFT

(2) **Supersonic flight from the pilots' view.** W. B. BRIDGEMAN. *Aero. Engng. Rev.*, **11**, (2), 24-28 (*Feb.*, 1952).
Experiences with the Douglas "Skyrocket."

(3) **Jet assisted take-off.** W. J. MERBOTH. *Sailplane & Glider*, **20**, (2), 6-7 (*Feb.*, 1952).
Use of the Aerojet JATO Junior for glider take-offs.

(4) **Aerodynamic research with rocket-propelled models.** *Engineer*, **194**, 245-255 (22*nd Aug.*, 1952).
Research at Pilotless Aircraft Research Station of N.A.C.A.

(5) **SO 6025 jet/rocket fighter tested.** *Aviation Wk.*, **57**, (8), 18 (25*th Aug.*, 1952).
Photos of new French aircraft built by SNCA du Sud-Ouest.

ASTRONAUTICS

See also abs. no. 15.

(6) **Meteoric collision factor in space-ship design.** F. L. WHIPPLE. *Aviation Age*, **16**, (6), 25-26 (*Dec.*, 1951).

(7) **Some effects of interplanetary hydrogen upon spaceships.** W. PROELL. *J. Space Flight*, **4**, (6), 1-8 (*June*, 1952).
Consideration of the effects of atomic hydrogen at low concentrations on metals. Concludes that appreciable deterioration of ship structures might take place and that protection may be needed for long periods of operation. (14 *refs.*)

(8) **Problem of traction.** D. H. CRONQUIST. *Pacif. Rocket Soc. Bull.*, **5**, (8), B7-B8 (10*th Aug.*, 1952).
Consideration of the use of wheeled vehicles on the Moon.

(9) **Establishing contact between orbiting vehicles.** R. A. SMITH. *Pacif. Rocket Soc. Bull.*, **5**, (8), B1-B6, C6 (10*th Aug.*, 1952).
Paper read at 2nd International Congress on Astronautics, London, 1951. Also published in *J.B.I.S.*, **10**, 295-299 (*Nov.* 1951).

(10) **Ascent from Earth.** L. GRANT. *J. Space Flight*, **4**, (7), 1-4 (*Sept.*, 1952).
Review of problems involved.

(11) **Astronautics at Stuttgart.** A. E. SLATER. *Aeroplane*, **83**, 456-457 (26*th Sept.*, 1952).
Short abstracts of the technical papers delivered at the Third International Congress on Astronautics.

(12) **A preliminary survey of the constructional features of space stations.** H. KETCHUM. *J. Space Flight*, **4**, (8), 1-4 (*Oct.*, 1952).

(13) **The practical approach to astronautics.** J. HUMPHRIES. *Flight*, **62**, 528, 532 (*24th Oct.*, 1952).

Review of several of the technical papers presented at the Third International Congress on Astronautics.

ASTRONOMY

(14) **Traces of atmosphere on Mercury.** B. M. RUBASHEV. *Priroda*, **40**, (11), 47 (*Nov.*, 1951). (*In Russian.*)

(15) **Results of rocket and meteor research.** F. L. WHIPPLE. *Bull. Amer. Met. Soc.* (*Jan.*, 1952).

A discussion of the possible dangers in space arising from micrometeorites.

(16) **The minor planets.** O. STRUVE. *Sky & Telescope*, **11**, 163-166 (*May*, 1952).

Short description of the asteroids.

(17) **Via the Moon.** *Sky & Telescope*, **11**, 194-195 (*June*, 1952).

Details of recent American work in obtaining radar echoes from the Moon.

(18) **Radio echoes from the planets.** B. BURRELL. *Observatory*, **72**, 118-119 (*June*, 1952).

Possibility of determining the strengths of the magnetic fields of the planets, particularly Jupiter, by radar methods.

(19) **Do we see a lunar tunnel?** H. H. NININGER. *Sky & Telescope*, **11**, 192-193 (*June*, 1952).

A suggestion that the twin craters, Messier and Pickering, were formed by a meteor piercing a ridge which would mean that they are connected by a tunnel. This might be used as a shelter from small meteorites.

ATMOSPHERE

See also abs. no. 25.

(20) **Flight in the aeropause.** R. HAWTHORNE. *Aviation Age*, **16**, (6), 29-31 (*Dec.*, 1951).

Summary of physical and physiological effects of flight at distances greater than 12 miles above the Earth's surface (**37** *refs.*).

(21) **High-altitude research.** E. BURGESS. *Engineer*, **194**, Pt. I, 338-340 (*12th Sept.*, 1952); Pt. II, 370-373 (*19th Sept.*, 1952).

First part deals mainly with telemetering equipment and second part with the various measurements taken and equipment used.

BIOLOGY AND MEDICINE

See also abs. no. 20.

(22) **Life on Mars in view of physiological principles.** H. STRUGHOLD. *U.S. Cen. Air Docum. Off.* (*N.-A.F.*) *Tech. Data Dig.*, **16**, 15 (*Nov.*, 1951).

(23) **Meeting of the Space Medicine Association.** *J. Aviation Medicine*, **23**, 544-547 (*Dec.*, 1951).

(24) **Standing broad jump.** D. H. CRONQUIST. *Pacif. Rocket Soc. Bull.*, **5**, (9), B1-B6 (*10th Sept.*, 1952).

Deduces that a man should be able to jump about 10 times as far on the Moon as on the Earth.

(25) **Manned flight at the borders of space.** H. HABER. *J. Amer. Rocket Soc.*, **22**, 269-276, 283 (*Sept.-Oct.*, 1952).

The major functions of the atmosphere for both man and craft are discussed. These are: contributing to respiration, preventing boiling of body fluids, sustaining combustion of fuel, absorbing heavy primaries of cosmic radiation, absorbing solar ultra-violet radiation, supplying aerodynamic lift, supplying diffuse daylight, absorbing meteors, interacting thermally with the craft and interfering by air drag over long periods of time (artificial satellites) (**33** *refs.*).

(26) **Exposure hazard from cosmic radiation at extreme altitude and in free space.** H. J. SCHAEFER. *J. Amer. Rocket Soc.*, **22**, 277-283 (*Sept.-Oct.*, 1952).

The heavy nuclei component of primary cosmic radiation is a possible hazard for

humans because of its extremely high specific ionization and the large radial spread of the dosage around the particle tracks. The distribution of the heavy particles is not known with any accuracy because of the deflecting effect of the Earth's magnetic field.

CHEMISTRY

(27) **Chemistry can solve many space-flight problems.** *Chem. Engng. News*, **30**, 4372 (*20th Oct.*, 1952).
Brief reviews of the chemical papers delivered at the Third International Congress on Astronautics.

MATERIALS

(28) **Magnesium in the N.A.C.A.'s pilotless aircraft.** C. C. JOHNSON. *Magazine of Magnesium*, 2-5 (*Nov.*, 1950).

PHYSICS

(29) **Mechanism and kinetics of the water-gas reaction during adiabatic expansion.** H. BEHRENS. *Z. Phys. Chem.*, **195**, 24-36 (*May*, 1950). (*In German.*)

(30) **Heat transfer in nitrogen and hydrogen sweat-cooled tubes.** H. L. WHEELER. *J.P.L., Galcit Prog. Rept. No.* 20-160, 27 pp. (*4th Jan.*, 1952).

PROJECTILES

See also abs. no. 1.

(31) **The temperature barrier of high altitude, long distance missiles. Pt. II. Dynamics of a missile with propulsive jet.** G. A. CROCCO. *Atti Accad. Naz. Lincei (R.C. Cl. Sci. Fis. Mat. Nat.)*, **11**, 3-10 (*July-Aug.*, 1951). (*In Italian.*)
Deals with the portion of the flight immediately after launching. [For Pt. I, see abs. no. 211, *J.B.I.S.*, **11**, 201 (*July*, 1952).]

(32) **Lunar parallax method of astro navigation.** J. S. THOMPSON. *Navigation*, **3**, 50-57 (*Sept.-Dec.*, 1951).
Design, components and operation of an instrument for automatic guidance of long-range surface-to-surface missiles, which is based on the measurement of the change in position of the Moon relative to the stars due to the motion of the missile over the Earth's surface.

(33) **Principles of missile guidance systems.** *Aero Dig.*, **63**, (5), 88, 90, 92, 94, 96, 98-103 (*Nov.*, 1951).
Surveys the various types of missiles and guidance systems. Considers the missile as a servo-mechanism and deals with the conditions necessary for stability.

(34) **Rocket realities.** N. S. CURREY. *Canadian Aviation*, **24**, (11), 20-21 (*Nov.*, 1951).
Brief summary of the history and future trends of rocket developments.

(35) **U.S.A.F.'s Guided Missile Test Centre.** R. E. STOCKWELL. *Aviation Age*, **16**, Pt. I (5) (*Nov.*, 1951); Pt. II (6), 40-43 (*Dec.*, 1951).
Description of test facilities including launching, tracking and control equipment.

(36) **What we have learned from V.2 firings.** D. A. ANDERTON, *Aviation Wk.*, **55**, (22), 23-24, 27, 29-30, 35 (*26th Nov.*, 1951).

(37) **Hydraulic device for servo-mechanisms.** *Aviation Age*, **17** (1), 29 (*Jan.*, 1952).
Device for missile applications.

(38) **Guided missiles, a new field for the radio engineer.** S. RAMO. *Proc. Inst. Radio Engrs.*, **40**, 3 (*Jan.*, 1952).
Outline of operational requirements.

(39) **Special engines.** M. VICTOR. *Revue de l'Aluminium*, (184), 31-39 (*Jan.*, 1952). (*In French.*)
General review of modern missiles with special reference to rocket propulsion.

(40) **Rockets for bazookas.** J. GESCHELIN. *Autom. Ind.*, **106**, 34-36, 86 (*1st Jan.*, 1952).
Production of the metal parts by Ford Motor Co.

(41) **A dispersion analysis of a stable missile.** R. J. GUNKEL. *Douglas Aircraft Co. Inc., Rept. No. SM-13427*, 55 pp. (*13th Jan.*, 1949).

(42) **Peenemünde, 1951.** *Aviation Age*, **17**, (2), 33 (*Feb.*, 1952).
Brief report on the facilities at the Russian guided-missile test station.

(43) **The guided missile—precocious problem child of the military art.** C. B. MILLIKAN, *Aero. Engng. Rev.*, **11**, (4), 52-56, 65 (*April*, 1952).
General review of development problems.

(44) **Missile guidance by stars.** P. PERNAZZA. *Riv. Aero.*, **28**, 503-515 (*June*, 1952). (*In Italian.*)
General review of celestial navigation with discussion of specific problems affecting application to missiles.

(45) **Fire drill.** *Aviation Wk.*, **57**, (6), 9 (*11th Aug.*, 1952).
Action photos of airborne rockets.

RADIO AND ELECTRONICS

See also abs. no. 21.

(46) **N.B.S. telemetering-in-flight calibrator.** *Nat. Bur. Stand. Tech. News Bull.*, **36**, (1), 5-6 (*Jan.*, 1952).
A 10-channel in-flight calibrator for identifying telemetered information from a guided missile.

ROCKET MOTORS

(47) **A central data-recording system for a jet-propulsion laboratory.** C. G. HYLKEMA, R. F. STOTT and H. S. SEIFERT. *Elect. Engng., N.Y.*, **70**, 957-960 (*Nov.*, 1951).
A group of recorders in one central location is used for recording quantities being measured in widely scattered test locations. The electronic recording equipment and test-bay installations are described.

(48) **Snarler.** *Hawker Siddeley Rev.*, **4**, 90-91 (*Dec.*, 1951).
Performance, specifications and construction details.

(49) **Propulsion by rocket.** S. ALLEN. *Canadian Aviation*, **25**, (3), 27, 55-56, 58, 60, 62 (*March*, 1952).
Description of the Armstrong Siddeley Snarler and its use in the Hawker P.1072.

(50) **Rocket power.** *Aeronautics*, **27**, 96-98 (*Sept.*, 1952).
Description of a visit to the Armstrong Siddeley rocket test facilities.

(51) **Effect of local variations in mixture ratio on rocket performance.** D. ALTMAN and J. LORELL. *J. Amer. Rocket Soc.*, **22**, 252-255 (*Sept.-Oct.*, 1952).
The effect can be evaluated by reference to a curve of theoretical specific impulse versus weight fraction. If such a curve has a negative second derivative everywhere, local variations can only decrease performance. If there is a region with positive second derivative, then local variations may improve performance.

(52) **Longitudinal vibrations of gas at ambient pressure in a rocket thrust chamber.** I. ELIAS and R. GORDON. *J. Amer. Rocket Soc.*, **22**, 263-268 (*Sept.-Oct.*, 1952).
An analysis is presented for the determination of the natural frequency in longitudinal vibration of a static gas mass at ambient pressure contained in a rocket chamber. Results from tests with chambers of three different configurations are presented in substantiation of the theoretical results.

(53) **Isothermal combustion under flow conditions.** K. SCHELLER and J. A. BIERLEIN. *J. Amer. Rocket Soc.*, **22**, 245-251, 287 (*Sept.-Oct.*, 1952).
It is shown that, in general, an isothermal expansion in a rocket motor is a less desirable cycle than an adiabatic cycle from point of view of thermodynamic efficiency and the practical problems of its application.

(54) **Servo-stabilisation of combustion in rocket motors.** H. S. TSIEN. *J. Amer. Rocket Soc.*, **22**, 256-262, 268 (*Sept.-Oct.*, 1952).
Combustion in the rocket motor can be stabilized against any value of time lag in combustion by a feedback servo link from a chamber pressure pick-up, through an appropriately designed amplifier, to a control capacitance on the propellant feed line. The technique of stability analysis is based upon a combination of the Satche diagram and the Nyquist diagram. Only low-frequency oscillations in monopropellant motors are considered, but the concept and method of analysis are believed to be generally applicable.

(55) **Closer liaison needed between combustion scientists, engineers.** *Chem. Engng. News*, **30**, 3832-3834, 3836-3837 (*15th Sept.*, 1952).
Review of some of the papers delivered at the Fourth Symposium on Combustion (M.I.T., 1st to 5th Sept., 1952). In particular, deals with papers on unstable burning in rocket motors.

ROCKET PROPELLANTS

(56) **Report on the development of protective clothing for handling liquid rocket propellants.** HAGAN. *U.S.A.F. Air Materiel Command, Engineering Div., Aero Medical Lab., Memo Rept. MCREXD-666-16K*, 11 pp. (*30th Oct.*, 1950).

(57) **Petroleum fuels in jet and rocket propulsion.** J. M. CARTER. *Proceedings of 3rd World Petroleum Congress*, Sect. V, 79-86 (1951).

Review of fuel requirements—concludes that petroleum fuels will continue to be used for the majority of applications.

(58) **The burning and structure of cordite.** J. D. HUFFINGTON. *Trans. Faraday Soc.*, **47**, 864-876 (1951).

Burning of cordite is shown to be an essentially intermittent phenomenon in which periods of quiescence are followed by periods of abnormally rapid burning.

REVIEWS

Across the Space Frontier

(Edited by Cornelius Ryan. 147 pp., 13 illustrations (7 in colour). Published by Viking Press, 1952. $3.95. Published in England by Sidgwick & Jackson, Ltd., London. 21s.)

This book is an expanded version of a series of articles published in *Collier's* some months ago which described, in the main, the establishment and uses of an artificial satellite, and supplies further general and detailed information for those whose curiosity has been aroused by the original articles.

It is divided into six main chapters, each of which is written by a different author.

The first, by Joseph Kaplan, describes what we know about the atmosphere which surrounds the Earth, and how its presence limits our knowledge of what goes on beyond it. The second chapter is by Wernher von Braun, and discusses how a space station could be established, and how it might be used as a spring-board for voyages into deeper space.

The third chapter is by Heinz Haber, and deals with the physiological problems which have to be solved, the possible dangers from meteors and cosmic rays, and the effects of weightlessness on personnel. This is followed by a chapter written by Willy Ley, which considers the satellite vehicle itself—how it is constructed, equipped, and replenished with vital supplies.

The fifth chapter, entitled "Who Owns the Universe" is written by Oscar Schachter and deals with the legal aspects of space flight, drawing parallels between the eras of exploration and discovery of a few hundred years ago with those of the satellite vehicle and lunar base of to-morrow.

The sixth and final chapter is by Fred Whipple and elaborates upon the many and various uses to which a space station could be put in extending our knowledge of astronomy, meteorology, physics, geophysics, and biochemistry.

The book is well illustrated by Bonestell, Freeman, and Klep, in the former's lucid photographic style which we have come to expect and admire.

One can, of course, find matters of criticism, as one always can. For example, the mass ratio estimations may be somewhat optimistic, and the choice of propellants questionable. The accent on the military use of the space station is possibly over-emphasized—at least one may hope so. The meteor and cosmic

ray dangers are, perhaps, exaggerated, whereas the observations regarding international rules governing space flight are perhaps a little naive and idealistic, although undoubtedly the problem which faces us is a truly vital one.

Regardless of criticisms, and most of these are matters of opinion, this is essentially a very readable book, and a worthy addition to any library on the subject.

W. N. N.

Rocket Propulsion

(By E. Burgess. 235 pp. Chapman & Hall, London, 1952. 21s.)

The appearance of a book by a British author, which is the first to be published in the post-war era dealing specifically with all aspects of rocket propulsion, is a noteworthy event. For this reason it would have been pleasant to record that it made an important contribution to the science of rocket propulsion; at best it must be described as disappointing.

According to the publisher's preface the book "is presented, not only as an introduction and fascinating story for the layman, but also as a useful work of collated data for students and specialists who require a handy reference book on the many aspects of the science of rocketry and its ultimate developments." Unfortunately, neither of these objects is achieved, since the book contains so many errors and statements of doubtful accuracy that it is misleading to the layman and of little value to the specialist.

These errors and mistatements are so common that they reveal a lack of knowledge on the part of the author of many aspects of the subject with which he is dealing, and also reflect on his revision and the checking of the draft before it was submitted for publication. In the first four chapters over 120 errors or statements of doubtful accuracy were noted, although in fairness it must be stated that the number is far smaller in the remaining chapters. It will obviously be impossible to comment on all of these and only brief mention will be made of some of the errors in each chapter.

Chapter 1. General Principles of Rocket Propulsion:

p. 11, para. 3. Mass is confused with weight. Force is equal to mass multiplied by acceleration, not weight by acceleration as stated. Weight is itself a force.

p. 12, para. 3. Recoil is not an effect of the velocity but of the acceleration.

p. 14, para. 3. The major application of solid propellant rockets is for providing short duration high thrusts, not short duration low thrusts as stated.

p. 27, para. 2. The effective mass ratio of the multi-stage rocket under consideration will not be 243 as reported, but 36. The author is not conversant with the method of calculating effective mass ratios.

Chapter 2. The Source of Energy: Fuel.:

p. 35, para. 3. The chamber volume increases, but the surface area of the powder remains roughly constant in solid propellant rockets employing a hollow cone charge design—it does not vary as stated. It is impossible to detonate gunpowder; any failures that occur are due to the body bursting due to increase in combustion pressure.

p. 36, para. 1. The author's terminology is here incorrect. The central cone of a black powder rocket is the "gallery" not the "spindle," which is the male former.

p. 37, para. 2. Solid propellants and high explosives are two different substances and cannot change from one to another spontaneously, as stated. A feature of high explosives is that they can be readily detonated, whereas only very few solid propellants can be detonated and then only with great difficulty.

p. 37, para. 3 and p. 38, para. 1. The author does not understand the term "smokeless powder." It is a generic name for a class of propellant which includes cordite, ballistite, Du Pont pistol powder, etc. They can be made with or without nitroglycerine.

p. 41, para. 3. Hydrazine is not an example of an amine in which one or more or the hydrogen atoms of ammonia are replaced by hydrocarbon or alcohol radicals. Aniline is an example of a substitution of this type.

p. 42, para. 2. Sodium or calcium permanganate was used as a catalyst, not a secondary fuel.

p. 42, para. 4. 8-hydroxyquinoline is a stabiliser for hydrogen peroxide and nitrous oxide is an oxidant. They are not fuels.

p. 53, Table. The reaction of atomic hydrogen with ozone releases approximately 56·5 kcal./gm. mol. (not 102·43) and has a maximum specific impulse of about 740—not 2,790 as reported. This is an example of faulty arithmetic.

p. 55, para. 2. Liquid fluorine monoxide does not have to be kept at lower temperatures than liquid oxygen since its boiling point is — 145° C. compared with — 183° C. for the latter.

Chapter 3. Using the Energy: The Rocket Motor:

p. 59, para. 2. Use of the terms "liquid-fuel" and "solid-fuel" to describe types of rocket motors is misleading. Rocket motors use propellants which generally consist of an oxidant and a fuel. Great care should be taken to avoid interchange and confusion of these three terms—propellant, fuel and oxidant. These terms are used indiscriminately throughout.

p. 68, fig. 12. The figure does not illustrate how pressure and excess of fuel can alter jet velocity as it is reputed to do. It is not, in fact, a plot in the normal sense of the word and is quite meaningless.

p. 79, para. 2. 30° is an average value for the angle of divergence of rocket nozzles, not 6–12°, as stated.

p. 79, Table 8 and para. 3. No details are given of the method of estimation used in arriving at Table 8 and the lengths reported for the divergent portion of the nozzles are far from those used in practice. This is admitted in para. 3 and there would, therefore, appear to be no value in reproducing the Table.

p. 85, para. 1. 3000° C. is an average value for the combustion temperature of solid propellants, not 2000° C. They do not burn at lower temperatures than liquid propellants.

p. 87, para. 3. Burn-outs of combustion chambers are generally caused by heat transfer difficulties and not by oxidation and erosion of the chamber.

An excess of oxidant over fuel does not invariably cause burn-outs, as many motors run oxygen rich.

p. 91, para. 3. With swiftly flowing fuel feeds, heat transfer is higher and therefore more heat will reach the outer jacket than when lower velocities are used. The statement that with swiftly flowing fuel feeds, very little heat should reach the outer jacket is therefore incorrect.

p. 94, para. 1. Refractories are in general unsatisfactory because of their inability to withstand thermal shock, not because of differences in thermal expansion.

Chapter 4. Problems of Fuel Feed and Fuel Tanks:

p. 101, para. 1. The statements that the burning surface area of the propellant varies and that constant reaction conditions are impossible are incorrect. A fundamental feature of the design of most solid propellant rocket motors, is that the burning surface area and hence the thrust are maintained constant. The chamber volume always increases but the surface area usually remains constant unless a progressive or regressive thrust-time curve is desired.

p. 109, para. 1. A gas-tight piston "floating" on top of a liquid is a mechanical impossibility.

Chapter 5. Control of Flight:

p. 128, para. 1. Modern life-saving rockets do not require, and do not use, a stick for stability.

p. 131, para. 2. It is incorrect to state that acceleration does not matter in the case of solid propellant rocket motors, as the upper temperature limit is partly fixed by the physical strength of the propellant, i.e., its ability to withstand acceleration.

Chapter 6. Long-range Rocket Projectiles:

p. 160, para. 2. According to the author's previous statement (p. 141, line 3), the error for a missile of 3,000 miles range should not exceed 300 yds., whereas here it is stated that the error should not exceed 10 miles in range and 3 miles laterally.

As well as the errors detailed above, and others, there appears to be avoidable repetition and misuse of technical terms. There was also, at least, for this reviewer, an annoying tendency of referring to the "Manchester Interplanetary Society" or "Manchester Astronautical Association" in support of many statements. More authoritative sources should be used as references in a book of this type.

Much important information has been omitted, e.g., practical propellant performance figures, discussion of compatibility of materials of construction with proposed propellants, the practical problems of heat transfer, shielding for nuclear powered rocket motors and much other important data that has been published, and is readily available.

In view of these errors and omissions this book in its present form cannot be recommended to the specialist, the student of rocket propulsion, or the layman.

A. S.

CORRESPONDENCE

The Design of Rocket Motors

SIR,

I am obliged to Mr. Ziebland for calling attention to the fact that heat transfer calculations are not as simple as I may have suggested. In a paper which tried to cover such a wide field, some simplification was necessary, although the failure to mention radiation, the part played by radiation in heat transfer might perhaps be called over-simplification.

The heat transfer at any point in the combustion chamber depends on the gas temperature at that point, and it is most important to choose the correct value for this. As Mr. Ziebland says, the appropriate gas temperature to be taken along the expansion nozzle is almost equal to the total head temperature.

It is difficult to see the physical significance of the slight drop in outer wall temperature with increasing wall thickness shown in Fig. 9. For the simplified conditions described in the paper, however, it is easy to show that it might be expected. Suppose that the nomenclature of the paper is used, together with

$H =$ conductance

$\Delta\theta =$ temperature drop.

At a given point in the combustion chamber, if only the wall thickness is changed, H_c, the liquid film conductance, and H_g, the gas film conductance, remain constant but H_w, the wall conductance, will vary inversely with thickness. If $\Delta\theta$ is the overall difference between gas the liquid temperatures,

$$\Delta\theta = \Delta\theta_g + \Delta\theta_w + \Delta\theta_c$$

And since $\Delta\theta = \dfrac{Q}{H}$

$$\Delta\theta = \frac{Q}{H_g} + \frac{Q}{H_w} + \frac{Q}{H_c}$$

So

$$Q = \frac{\Delta\theta}{{}^1/H_g + {}^1/H_w + {}^1/H_c}$$

If H_w is decreased by increasing the wall thickness, then Q will decrease. Since $Q = H_g.\Delta\theta_g = H_c.\Delta\theta_c$, this means that both $\Delta\theta_g$ and $\Delta\theta_c$ will decrease. This implies that the temperature of the hot side of the wall will increase while the temperature of the cold side will decrease.

I will add that my Fig. 9 is based on some calculations made from an actual combustion chamber by Mr. H. L. G. Sunley, to whom I am indebted for much useful advice on this subject.

D. HURDEN.

Leamington Spa, Worcs.

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Edited by Cornelius Ryan

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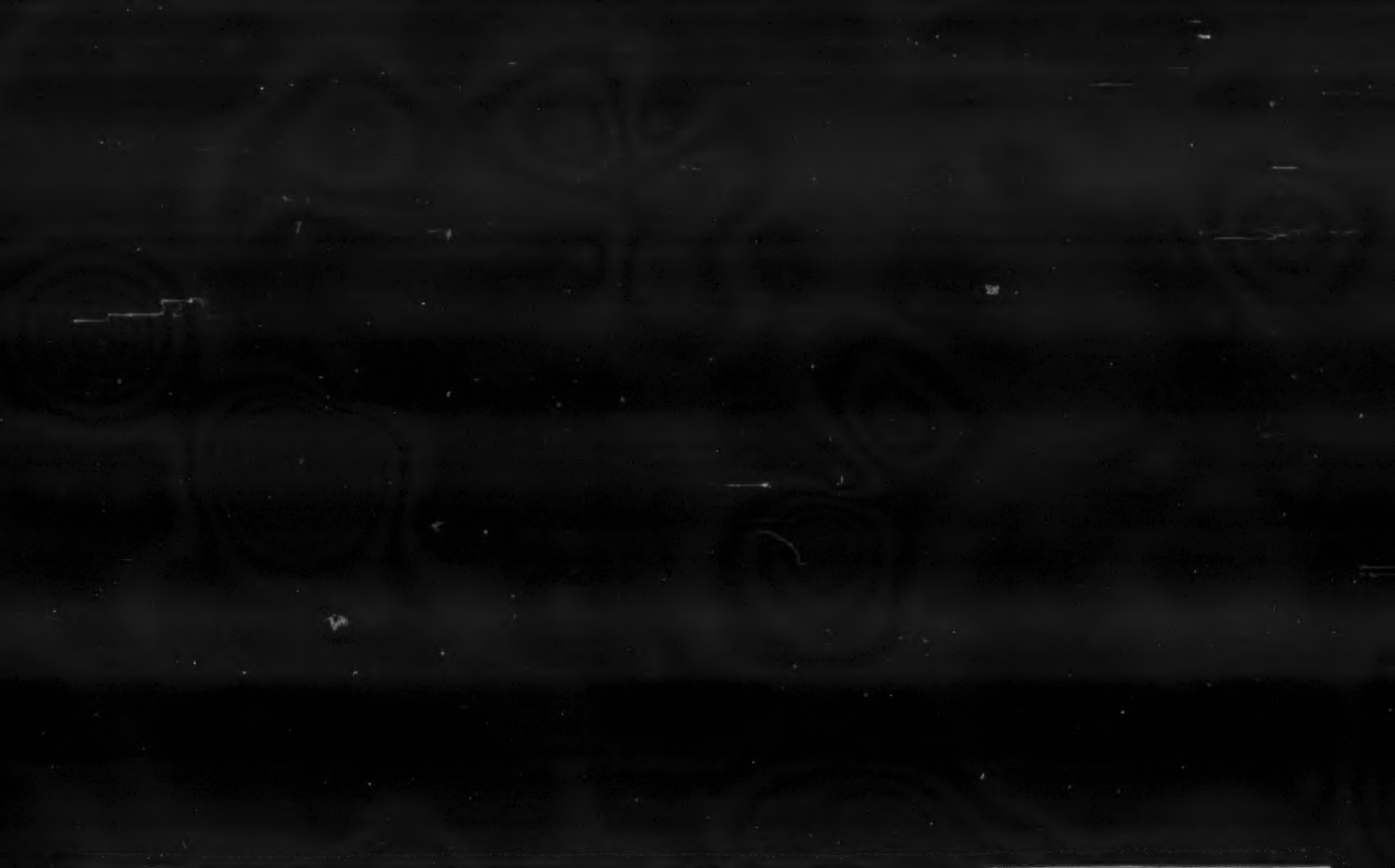
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